MAY 1 8 1932

DISCOVERY

A Monthly Popular Journal of Knowledge

Vol. XIII. No. 149. MAY, 1932. PRICE 1s. NET

TAKING THE TEMPERATURE OF SNAKES.

(See page 147).

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A Monthly Popular Journal of Knowledge

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Publishers: Benn Brothers, Ltd. All communications respecting editorial matters to be addressed to the Editor; all questions of advertisements and subscriptions to the Manager.

Offices: Bouverie House, Fleet Street, London, E.C.4. (Closed on Saturday.)

Telephone City 0244. Telegrams: Benbrolish, Fleet, London.

Annual Subscriptions 12*s.* 6*d.* post free anywhere in the world. Single numbers 1*s.* net; single back numbers more than two years old, 1*s.* 6*d.* net; postage (inland and foreign) 2*d.*

Binding cases, price 2*s.* 6*d.* net each; postage 6*d.*

Notes of the Month.

We publish this month a full account of the discovery of the neutron. Many discoveries are made by accident, and in a limited sense this is true of the neutron. But whereas its existence was suspected some twelve years ago, this particle had to make itself known through the very sensitive instruments used at the Cavendish Laboratory, Cambridge. For a long time radiations have been observed and recorded in this famous laboratory, where Dr. Chadwick has made some of the most remarkable researches of modern times. These patient labours have led to the discovery of a new kind of particle, which, as our contributor shows, opens up many fascinating problems.

* * * * *

New evidence bearing on the pre-dynastic peoples of Ancient Egypt has been brought to light by the Egypt Exploration Society at Armant. In his preliminary report, Mr. O. H. Myers calls attention to certain objects of painted plaster on a foundation of coarse canvas, which may be examples of flags, standards of the nomes or territorial divisions into which Ancient Egypt was divided. Usually these standards were solid objects, representing animals and so forth. Other discoveries include some beds of various types, one of which still has coarse linen sheets attached to it, fastened over and below—a unique find. To the Egyptologist, however, the most significant result is the evidence of the Badarian civilization, which preceded the pre-dynastic, two hundred miles south of the sites on which it was originally discovered by Sir Flinders Petrie and Mr. Guy Brunton.

* * * * *

Sir Arthur Keith's address on race prejudice before the Universities Congress at Oxford was a bold attack on current problems of international politics from the anthropologist's point of view. He holds that the feeling for race and nationality is an all-powerful factor in the upward struggle of mankind. The evolutionary process, as he sees it, is one which leads to more, and possibly better, races rather than an organism for the production of wealth. It is this disparity between the result of evolution and man's economic needs which is the cause of the disharmony in the world to-day. The problem is how and in what conditions can this racial and national spirit be rationalized, so as to work harmoniously towards international peace. Science has no national boundaries, and as a man of science Sir Arthur Keith may be unduly optimistic in his reliance on the powers of reason. Recent events suggest that it may be long before the peoples of the world will, as he suggests, be prepared to submit their national impulses to examination, education and, if need be, self-sacrifice before allowing them to emerge into action.

* * * * *

It is announced that Dr. Junker, of the German Institute in Cairo, has discovered the site of a large Byzantine settlement in the desert at Kashem el Gand. The discovery is remarkable because the region of the site is quite uninhabitable to-day, even by the Beduins. The settlement is thought to date from the fifth century A.D., and water was evidently obtained from rain-water cisterns. The site is apparently the remains of a military post since it is completely isolated. Dr. Junker came upon it in the course of an expedition to the Libyan Desert, and he hopes to return later to carry out excavations.

* * * * *

An interesting study in human physiology is being made by Dr. Benedict at the Carnegie Institution of Washington. Experiments on snakes have thrown

*

new light on heat production and the temperature of the body, which are important factors in studying disease. The body temperature of human beings and of nearly all warm-blooded animals remains constant under normal conditions, regardless of the surrounding temperature. In the Arctic climate, for instance, the polar fox registers a temperature even higher than that of man. The temperature of the cold-blooded animals, on the other hand, is affected by its surroundings. In the case of the snake it varies with almost mathematical regularity with the changes in the heat of the room. The study of cold-blooded animals is proving of great assistance in interpreting the abnormally high temperature of human beings during fever. The experiments are described on another page by Dr. Benedict, who foresees the solution of several problems in human physiology when the work is completed.

* * * * *

Five musk-rats were introduced into Europe from North America in 1905. To-day there are 100,000,000 on the Continent, and their introduction into Scotland and parts of England is likely to lead to a similar plague here unless control measures are taken. The musk-rat builds an elaborate network of tunnels, undermining river banks and obstructing drains. In Austria, where it is most prevalent, fields have been flooded and drainage systems seriously disorganized over large areas. By an order which comes into force on May 1st the importation and keeping of the animal in Great Britain is prohibited. The dangers were clearly illustrated at a recent exhibition at the Science Museum, South Kensington, which included a model of the animals and their intricate burrows, thus assisting the public to identify them. The destruction of the musk-rat is difficult as it appears only after dark, and the entrance to its burrows are beneath the surface of the water. Hence its presence is not detected until the damage has been done.

* * * * *

The value of divining has often been disputed, but in Italy, at any rate, *bonâ fide* dowsers are determined to expel the pretenders who have brought discredit on their science. At an international congress in Verona it was resolved to form a union of diviners, and in future only members of this body, holding a diploma, will be recognized. Two hundred diviners from various countries attended the meeting, which was called to discover, "if possible, a scientific interpretation of the phenomena of rhabdomancy." Professor Cazzamalli, of the University of Milan, suggested that its source was to be found in the human brain, "under special and uncommon activities." But Dr. Casu, of Verona, contended that divining was purely physical. Any substance capable of radiating electro-magnetic energy produced a muscular contraction made visible by the movement of the rod. Dr. Casu believes that divining will bestow many benefits on science, not only in the discovery of underground water and minerals but also in climatology and hydro-mineral therapeutics. After further discussion the congress passed the rather obvious resolution that "it is necessary to distinguish the phenomena of divining from the charlatanism which discredits rhabdomancy in the eyes of the public"!

* * * * *

In a lecture at Bedford last month the Master of the Rolls, Lord Hanworth, discussed the preservation of ancient documents. As reported in *The Times*, he said that this work was part of a much larger movement of modern times. No generation had done so much as our own for the reconditioning of old buildings, the preservation of important and historical sites, and the renovation of books, furniture and pictures. It was now the turn of the great historical records which deserved to be preserved and in respect of which we must overtake the ravages of time. Referring to manorial records, Lord Hanworth said he was very anxious that these documents should be collected and preserved in the counties to which they referred. We ought to be zealous in safeguarding for future generations what might be called the raw material for students.

* * * * *

Some important coins have been added to the British Museum's collection, including one of the rarest gold coins of Augustus, struck in 16 B.C. The obverse is a bust of Victory, of high artistic merit, while the reverse is of historical interest since it records an offering of vows by the Roman State for the health of Caesar. Augustus is not known to have had an illness at that date, but his health was delicate and the vows may have been inspired by anxiety on this score and in view of the voyage which he made to Gaul in the course of the year. Only two other specimens of the coin are known. The other coins include an unique Greek electrum of c. 600 B.C. from Asia Minor, and a number of coins of the medieval Indian State of Malwa, many of which correct and supplement the scanty historical records.

* * * * *

Faced with a nice point in tariff procedure, the Board of Customs has succeeded in solving a problem in biology which might otherwise have remained a mystery. The monkey's paw is in future to be regarded as a foot!

The Discovery of the Neutron.

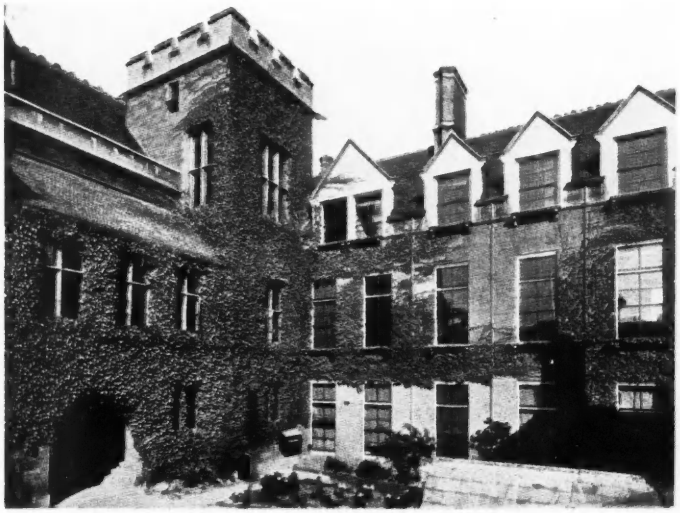
By A. S. Russell, D.Sc.

We had hoped that Dr. Chadwick, who discovered the neutron, would himself have written this article, but he begged to be excused. Accordingly we asked Dr. Russell to summarize the published data on the subject; he was formerly a colleague of Dr. Chadwick's in Lord Rutherford's laboratory at Manchester.

THE neutron is the latest candidate for that select class of ultimate particles of which the proton (the unit of mass and of positive electricity) and the electron (the unit of negative electricity) have for many years been the only members. The name, as classical readers will agree, is not a particularly happy one, but the thing itself is one of the most exciting things that has come to light in our time. It is simple to understand—it is the proton in *intimate* contact with the electron—but it has not been simple to discover. If it had been, it would long ago have been found. The credit for discovering the neutron must go to Dr. Chadwick of the Cavendish Laboratory in Cambridge, although, as is so often the case, preliminary work of great importance was done by others. It was discovered in experiments in which the tiny nuclei at the centre of certain light elements were bombarded with the swift massive particles spontaneously ejected by the element polonium.

As many readers are aware, from a bombardment of nitrogen, aluminium and other elements in this way, the alchemist's dream of changing one kind of element into another has been undoubtedly effected on an exceedingly minute scale. The atom of nitrogen, for example, weighing 14 on the usual scale of atomic weights, when bombarded by a swift charged particle of helium weighing 4 coming from polonium, may be momentarily fused with it into a mass of 18. This then splits, not into the particles which formed it, but into a charged atom of hydrogen weighing 1 and moving very fast, and a new type of oxygen atom weighing 17 moving slow. This is the typical happening in such transmutations: a new and heavier atom is formed and a charged atom of hydrogen makes its appearance. Since the War about a dozen different light elements have been found by ingenious and elaborate technique to submit to changes of this kind. Some, however, have resisted, and it has been provisionally and for obvious reasons concluded that certain elements have in the insides of their atoms a charged atom of hydrogen, while others have not.

The element beryllium is in strange case; it might belong to either class. The result of its bombardment was therefore looked forward to with more than usual interest. Professor Bothe, now of the University of Giessen, and his colleague Dr. Becker, were the first to investigate this problem. They found that beryllium behaved anomalously in giving neither of the alternative results. Instead, a small quantity of highly penetrating radiation was produced and this was ascribed to a gamma-ray, a well-known, high-energy, electromagnetic wave, one of the commonplaces of radioactivity. The investigation begun in Germany was continued in Paris by Mme. Curie's daughter and her husband M. Joliot. They observed that the new radiation from beryllium had rather a strange property for a gamma-ray, namely, the ability to knock charged particles of hydrogen out of paraffin wax and other hydrogen-containing material, placed in the path of the beam with a view to determining to what extent it absorbed it. Their interpretation of this interesting result was that the radiation was a gamma-radiation of unusually high energy, and there the matter rested for a time.



THE CAVENDISH LABORATORY FROM THE INNER COURT. [*W. H. Hayles*

It is often said that the greatness of the discoveries made by the present generation is due not to its being so much cleverer than former generations, but to the excellence of the instruments and general technique which are employed. Technique certainly contributed a great deal here. In the Cavendish Laboratory is a set of instruments over which Dr. Chadwick and his colleagues preside, of which they are very proud, which register accurately, automatically and to a very great degree of sensitivity, particles and radiations of many kinds. (For example, a cosmic ray when it emerges from the blue automatically turns on the apparatus which registers it.) In a very short time it was found that the paraffin-wax phenomenon was shown by other substances. Atoms of helium, lithium, carbon, oxygen and nitrogen, as well as those of hydrogen, were found to be set in violent motion by impact with the new radiation as though struck hard by an energetic billiard ball—as well they might, because it has turned out that the exciting cause is a particle with a velocity initially about one-tenth of that of light.

Experimental Evidence.

The speeds with which these atoms were set in motion, the tracks they registered, and the energies they displayed in the apparatus led Dr. Chadwick to improve on the provisional hypothesis put forward on the Continent, of the wave-like nature of the exciting cause. Well-tested generalizations like the conservation of energy and of momentum which are axiomatic to all good physicists would have to be abandoned if the cause were a *radiation*. What then? There remains only a particle. It must be neutral (a thing a particle has never been before) because direct experiment showed that it is neutral and because it is so penetrating; it has to be capable of coming out of the inside of the beryllium atom, for that is one of the few places whence it arises. The simplest hypothesis to embrace these points is to visualize an electron and a proton (a charged atom of hydrogen) in the closest possible contact. This would have a mass of 1 and a charge of 0 and could arise from beryllium. All the experimental evidence favours this view and is against the more conservative view that it is some kind of gamma-radiation.

We thus get a third kind of ultimate particle by the not very complicated process of combining the first two bodily. Why, it may be asked, has no one thought of this before? The answer is that one has. Twelve years ago Lord Rutherford, in the Bakerian Lecture to the Royal Society, fathered the idea as a possible brick in the building up of complex from simple atoms. Neutrons were indeed looked for in the strong electric discharge through hydrogen. It was hoped that some of the electrons might be induced to join up, as they are thought to be in the neutron, with some of the hydrogen atoms. No neutron, however, was found. Until the other day the neutron was an idea only. Nobody knew how to set about discovering it. It had, in the event, to force itself on the notice of atomic physicists; as we have seen, in the early experiments it was unrecognized.

The discovery of the neutron has opened a region of research which is of great interest and promise. The mathematician will begin with renewed energy to determine its place in the structure of the nucleus. (It would appear now that the nucleus of beryllium consists of two charged atoms of helium and one neutron.) The atomic physicist will determine what other elements produce neutrons in this way. (Already there is evidence that both boron and the gaseous element flourine behave similarly to beryllium.) Does the neutron, when it hits a nucleus, go slap through it, as a ghost is said to go through a wall, or does it rebound or stay incorporated in its target? These are some of the immediate problems for experimental investigation.

There is an interesting difference between neutrons and atoms which is easily understood. Atoms are afflicted with certain fields of force which prevent their fellows from coming nearer than a certain minimum distance; not so the neutrons. If neutrons could be mass-produced they could be packed so tightly together that the density of the mass would be that of an individual. This is known, because the mass and the volume of the hydrogen particle are both accurately known, and the density is the former divided by the latter. On the scale of densities in which water is 1, lead 11 and the heaviest known metal about 21, neutrons are distinguished by a density of approximately a thousand million millions! It is an obvious conclusion from this figure that neutrons are unlikely to pack together after mass-production.

A wine-glassful of neutrons presents a pretty subject for speculative thought. The neutrons would be so heavy that it is expected that they would break the glass. But they need not, because, in their rush towards the centre of the earth under the influence of gravity, their minute size and freedom from electric charge would enable them to thread their way through the atoms of the glass far better than any known electrons or protons. What would happen to them when they stopped, if they did stop, is a nice point, but one for experiment and not for speculation.

Science and Industry—III

The Age of Metals.

By Sir Harold Carpenter, F.R.S.

Outstanding progress in our knowledge of metallurgy has been made in recent years. New processes have been discovered and scientific research has resulted in greater reliability, increased supplies and a considerable reduction in cost.

UNDOUBTEDLY the first metals used by man were the pieces of copper, silver, gold and meteoric iron found on the surface of the earth, but thousands of years elapsed between the first use of the metals as peculiar types of stone and the discovery of the art of extracting metals from ores. The exact date of this discovery is, of course, unknown, but the Egyptians were well acquainted with the extraction of copper in the predynastic period, before 3400 B.C. Mining followed naturally from the use of metals. Ore was first obtained from the surface outcrop of veins and seams, but following the seams in quest of ore led to the construction of underground workings.

Primitive Methods.

From the introduction of the first primitive methods of extracting copper and iron until about four hundred years ago, the art and practice of metallurgy advanced very slowly, first in Egypt, Syria and India, then in Greece and the Roman Empire, and after a period when all advances were in abeyance, fairly rapid developments occurred in Renaissance Europe.

During the last four hundred years the growth and expansion of civilization has proceeded in intimate association with the discovery of new metals, new supplies of ore, new uses for metals, and new manufacturing technique. Other civilizations like those of Egypt, Greece, Rome, India and China were based on what we should regard as very rudimentary metallurgical achievements, but these cultures were not predominantly technological like that of the West. At the present time the world is more dependent on mining and metallurgy than at any time in the past.

It is difficult to assign even an approximate date to the first application of science to metallurgy. Different conceptions of science lead to differences of centuries in this respect. The scientific habit of mind, first attained by the Greeks, reappeared in Europe in the thirteenth century, but it was some centuries later before any marked change took place in man's mental attitude towards physical phenomena. This renewed interest in physical things undoubtedly affected the industries under consideration, but not to a very pronounced extent. Until as recently as a century ago changes in metallurgical practice were mainly the result of chance discoveries, or the application of ideas originating spontaneously in the minds of those engaged in the art. There was no definite urge to progress. Improvements were accepted when they appeared and new metals were utilized when they were discovered, but no conscious effort was directed to those ends.

The alchemists were the first to concern themselves with investigations designed to affect the metallurgical arts in an economically beneficial manner, but their aims were too ambitious, and their efforts to convert base metals into gold had little direct influence on metallurgy. It was not until many centuries later that it became generally realised that every stage and every process in the extraction of metals from their ores and in the application of them to useful purposes was susceptible to improvement, development and refinement, by systematic investigation. It was only then and not more than a century ago that science began to be effectively applied to metallurgy.

Metals are obtained from ores, i.e., from minerals containing the metals in sufficient quantities to make it economically profitable to extract them with the means available at the time. The processes of extraction vary from metal to metal, and for a given metal the details of the process vary with different ores. In a general way, however, the art of mining and metallurgy may be said to comprise the location of ore deposits, the mining of the ores, their preparation for smelting, and the smelting and refining processes. These processes are frequently followed by a number of other operations that are applied to some metals and not to others, such as alloying, hot-working, cold-working, heat-treatment, protective coatings, etc. All these operations are conveniently grouped together as subsequent treatment.

Industrial Uses.

The industrial and domestic use of metals depends on certain of their properties which may be described as mechanical, electrical, and chemical. To these must be added considerations of price and available supply, for no matter how useful a metal may be it cannot be employed to advantage unless it can be obtained in adequate quantities and at a price commensurate with its utility. The converse is also true

for the extraction and fabrication of a metal will not be profitable unless it possesses some atrribute that makes it the most suitable for some particular purpose.

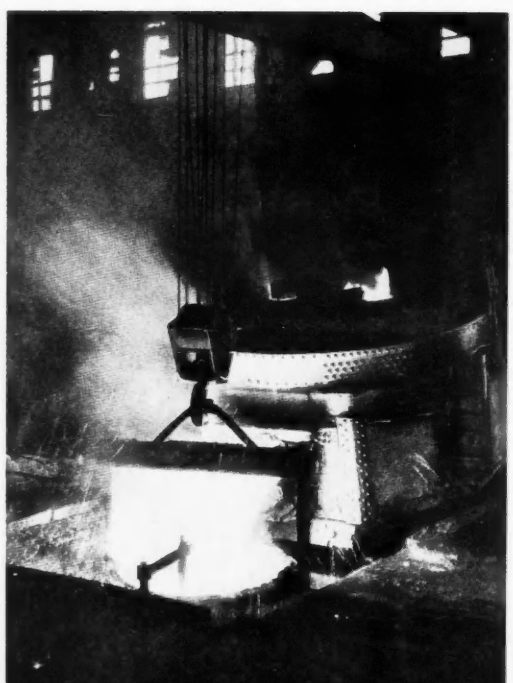
Metals are mainly used because of their mechanical properties, and their outstanding characteristic is the combination of strength with ductility and malleability. Materials like stone and wood can only be shaped by carving, and materials like clay and plasticene, which can be shaped by working, have little strength. But metals, because of their fusibility can be shaped by casting, because of their malleability can be shaped by working at high temperatures, and because of their ductility can be shaped by working at atmospheric temperature. The working processes applied to metals include pressing, rolling, hammering, extruding and stamping.

Next in importance come the electrical properties, upon which the whole of the electrical engineering industry depends. Copper is used extensively because of its ability to conduct electricity without loss. Tungsten and nickel-chromium alloys are used because they exhibit a relatively high resistance to the passage of an electric current and so convert electrical energy into heat and light. Pure iron, silicon-iron, permalloy, and mumetal are used because they can be magnetized and demagnetized without loss, while certain special types of steel, *e.g.*, tungsten steel and cobalt steel are used because they can be permanently magnetized.

It is difficult, however, to assess the value of the chemical properties of metals because these are frequently incidental to other uses. Thus the chemical properties of iron and steel are a definite disadvantage, for they result in the rapid corrosion of the unprotected metal in water, steam or a polluted atmosphere. The chemical properties of nickel-copper alloys, stainless steel, and aluminium are better from the point of view of useful application than those of iron and ordinary steel. This means that as a rule these metals can be used without the same protection as is required for iron and steel, and with less apprehension about the possibility of their failure as a result of corrosion. It also means that they are used in place of steel when resistance to corrosion is of paramount importance, as in the handling of foodstuffs and chemicals.

The motive underlying the scientific investigation of the properties of metals and of the processes employed in their extraction and fabrication is fairly simple. The purpose of metalliferous mining and metallurgy is to supply metals to satisfy the expanding demands of mechanical, electrical and chemical engineering, as well as those of the industries that cater for domestic needs. To serve these ends scientific research is applied to the study of metals in order to increase their reliability, to provide a greater variety, to ensure increasing supplies, and to reduce the cost. Numerous advances of varying degrees of importance have been made particularly in the last thirty years and it is only possible to mention a very small proportion of them.

It is appropriate to begin a brief outline of the most important scientific investigations by describing some of the studies of mechanical properties. When it is proposed to construct a bridge, a steel-frame building, a ship, a turbine, a boiler, or an aeroplane engine, it is necessary to design the work so that each part will be sufficiently strong to withstand with a sufficient margin of safety the forces that will be applied to it. In order to do this the magnitude of the forces and the mechanical properties of the metal must be known. It is obvious that if the strength of the metal and the intensity of the applied stress are known accurately the margin of safety may be made quite small, whereas, if there is some doubt about either or both of these quantities, the margin must be very large. From the point of view of efficiency and economy it

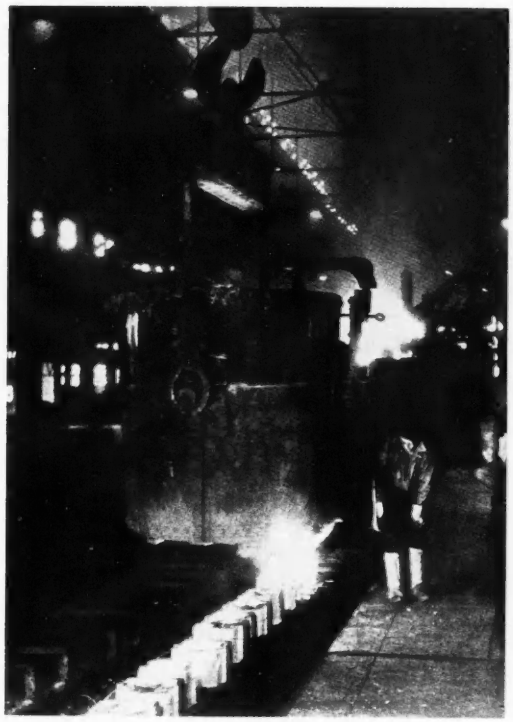


MOLTEN STEEL.

Much research has been devoted to heat treatment of steel. The photograph shows molten steel passing from the furnace to the ladle.

is always desirable to use as little metal as possible and in aircraft construction this is imperative. Consequently, while engineers have been perfecting the methods of calculating stresses, metallurgists have been studying mechanical properties.

In order to break a metal by the steady application of a force the latter must be of a certain magnitude. This is easily determined, and it is possible to ensure that metals used in construction will never be broken in this way. It has been discovered, however, that metals may be broken by the repeated application of a force much less than this. This phenomenon is known as "fatigue," but this is not a very suitable term. It implies that the life of the metal might be prolonged by periodic resting, and this is not the case.



INGOT MOULDS.

The molten steel passes from the ladle into a series of ingot moulds, shown above. All the photographs are reproduced from "Metal Progress."

As a result of the developments in high speed reciprocating engines, turbines, automobiles and aircraft, the phenomenon of fatigue has been growing more and more important since the beginning of the century. Some of the parts of machines are subjected to 1,000 million applications of stress in a normal period of service, and it is therefore necessary to determine the stress that may be safely applied to a given metal many millions of times. Numerous special machines have been devised for doing this, and the investigation of the fatigue-resisting properties of different metals after different treatments has been undertaken in laboratories all over the world.

Until about 1910 it was thought that even the smallest stress would eventually break a metal if applied a sufficient number of times. This idea arose because the tests were not continued long enough. Later tests in which the metals were subjected to 100 to 500 million applications of stress revealed that for each metal a certain maximum stress is required to produce failure. This stress is known as the fatigue or endurance limit of the metal and any lower stress may safely be applied an indefinite number of times. The endurance limit of a metal when accurately determined is a quantity that may be used with assurance by the designer of engines and machines. It is affected, however, to a pronounced degree by several subsidiary factors. Thus if there are any sudden changes in the cross-section of a part, *e.g.*, any tool marks, scratches, or discontinuities on its surface, or if it is in contact with any corrosive media like water, steam or salt solutions, the fatigue limit may be greatly reduced. For these reasons cranks are liable to fracture at the junction of the web and the shaft, screw threads and keyways are points of danger, and for high endurance all parts must be well finished. The endurance of spiral and laminated springs which are used without final grinding is much less than that of the steel of which they are composed, and heavy shafts have been known to break because an identification mark had been punched on them.

At atmospheric temperature any of the metals used in construction will withstand for an indefinite time any steadily applied force less than that required to break them. Time does not affect their strength. At higher temperatures, however, they may be fractured by the prolonged application of a stress much smaller than that required to break them in a few minutes. At these temperatures the metal slowly extends and eventually breaks. Failure is therefore a matter of time. The phenomenon is known as "creep," and it has become very important in connexion with the construction of internal combustion engines, high tension steam boilers, turbines using superheated steam, and any other structure or machine in which steel is heated above 300° C. Extensive investigations have been carried out to discover the highest stresses that steel and certain other metals will withstand for a very long time and to find types of steel and other alloys suitable for employment at high temperatures.

Steel is primarily an alloy of iron and carbon, and one of its most conspicuous attributes is the extent to which its properties may be affected by the rate at which it is cooled from above a certain range of temperature. The early Egyptians knew that steel could be made much harder by quenching in water, but the reason for this long remained a mystery and it was not until the present century that the application of scientific research led to any real knowledge of the subject. The phenomena involved are very complicated, and a satisfactory explanation has only been found after numerous investigations in which all the available physical and chemical methods have been employed. As a result of a better understanding of the changes that take place in steel during cooling and of the effect on these of the rate of cooling and the composition of the steel, it has now become possible to introduce great refinements in heat treatment and to take full advantage of the effect of adding elements like nickel, chromium, manganese and molybdenum.

Martensite Steel.

Steel solidifies as a solid solution of carbon in iron known as austenite. During slow cooling this breaks down to an aggregate which consists of crystals of pure iron (ferrite) and a compound of iron and carbon (cementite). If the cooling is rapid enough, however, this change may be prevented, and the austenite transforms at a lower temperature to another constituent called martensite. These three different states in which the same steel may be obtained have very different properties. Martensite is very hard and brittle, the aggregate of ferrite and cementite is relatively soft and ductile, while austenite, when it can be obtained at atmospheric temperature, has quite unique properties.

For ordinary constructional purposes, *e.g.*, buildings, bridges, rails and ships, it is convenient to use steel consisting of ferrite and cementite. For tools martensite is required, and for many parts involved in the manufacture of automobiles, aeroplanes, war vessels, guns, gears, etc., martensite that has been heated to produce a slight softening is essential. The salient feature of the heat-treatment of steel is therefore to produce martensite. In plain carbon steels martensite may be produced in small articles by quenching in water, but it is frequently necessary to obtain this constituent in heavier articles and it is always undesirable, on account of the danger of cracking, to quench the metal in water. Some means of reducing the rate of cooling required to obtain martensite is therefore essential. This has been found to result from the addition of manganese, nickel, chromium and molybdenum to the steel.

Numerous investigations on the heat treatment of steel and the effect of alloying elements have led to the introduction of several hundreds of varieties containing the above-mentioned metals and many others in different quantities and different combinations. The primary object of all these variations in composition is, however, to facilitate the production of martensite. The alloy steels are, therefore, conveniently classified as oil hardening and air hardening, in accordance with the rate of cooling required to obtain this constituent. There are, however, a number of alloy steels in which the primary function of the alloying elements is not connected with the production of martensite. Among these may be mentioned high speed steels, austenitic manganese steels and stainless steels. High speed steels are used for tools. They contain about 18 per cent of tungsten and their particular property is that they retain their hardness when heated and may therefore be used at high cutting speeds. Austenitic manganese steel is used whenever metal is required to resist both shock and heavy wear.

In general hard metals which resist wear are peculiarly liable to fracture by shock. Soft metals which resist shock are easily worn away. Austenitic steel is intrinsically soft or tough, but if any attempt is made to cut, machine, file, or wear it away, the surface layer changes to martensite and resists the tool. This steel is always tough but its surface is always hard. Consequently it is invaluable for railway points, crossings, etc., for certain kinds of gears, and for stone and ore crushers.

Stainless steel is, of course, one of the most important discoveries of the present century. The susceptibility of steel to electro-chemical corrosion in water and air, and to rapid oxidation at elevated temperatures has always been a serious technical and economic disadvantage. It has restricted developments, caused loss and accidents, and frequently compelled the use of metals of inferior mechanical properties. The use of stainless steel has enabled many difficulties to be overcome, but its price prevents its wider application.

High Temperatures.

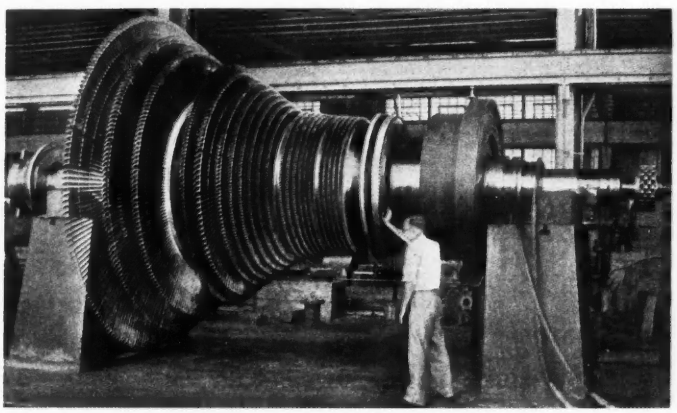
This steel owes its high degree of resistance to chemical action to the presence of large proportions of chromium—usually more than 11 per cent. Curiously enough, chromium confers this resistance as a result of its great affinity for oxygen. In the atmosphere, in water, in salt solutions, and in certain acids, the chromium forms a continuous adherent

oxide film on the surface of the metal which effectively protects it from further attack. This same property accounts for the resistance to high temperature oxidations of the nickel-chromium alloys, and makes them suitable for electric heating elements and a great variety of other purposes where high temperatures are used. A similar property exhibited by aluminium is responsible for the comparatively high degree of resistance to corrosion shown by this metal and its alloys. It is now known that such resistance is not peculiar to the noble non-reactive metals like gold and platinum. Under suitable conditions reactive metals which possess the property of forming coherent and insoluble films are also highly resistant to corrosion.

There are three principal types of stainless steel. Low carbon stainless steel, frequently called stainless iron, contains less than 0.12 per cent of carbon and from 11 to 12 per cent of chromium. It is used in the slowly cooled condition, *i.e.*, it contains ferrite and cementite. This steel is the stainless equivalent of ordinary mild steel. Cutlery steel, so called because it was first used for knives, contains 0.3 per cent of carbon and from 12 to 15 per cent of chromium. It develops its greatest resistance to corrosion when it consists of martensite and is almost invariably used in the hardened condition. Austenitic stainless steel has the highest resistance of all to corrosion and is the most generally useful of the stainless steels. It is not so readily converted to martensite as austenitic manganese steel and is suitable for cold shaping. Its composition varies widely, but it always contains a large proportion of nickel in addition to chromium. A popular type contains about 8 per cent of nickel and 18 per cent of chromium.

All the common metals have been known for a long time, but some of them, notably aluminium and tungsten were not available for industrial purposes until the present century. Neither of these metals can be extracted from its ores by the old established and basic methods of metallurgy and new methods had to be devised.

Aluminium cannot be freed from its ores by the ordinary methods because its great affinity for oxygen makes it impossible to reduce the oxide by means of carbon or reducing gases. The same difficulty is encountered with magnesium and beryllium, and although research has been actively pursued for many years it has not yet become possible to make pure beryllium, which may ultimately prove a useful metal. Aluminium is now obtained by the electrolysis of the mineral bauxite, which is dissolved in a bath of molten cryolite (an aluminium sodium fluoride). The hearth of the furnace is made of carbon and serves as the cathode. Carbon anodes are used, and the electrolysing current supplies the heat to melt the cryolite. During the electrolysis the aluminium oxide (bauxite) is decomposed, oxygen is liberated at the anodes, and aluminium collects on the hearth.



A LARGE TURBINE ROTOR AND BLADING.

In the manufacture of tools martensite steel is required, while for many parts involved in the construction of gears it is essential to use martensite that has been heated to produce a slight softening.

The outstanding property of aluminium is its lightness, but the pure metal, although very useful where ductility is required, is too soft for constructional purposes. This has led to very extensive investigations on the effect of adding comparatively small quantities of other elements in order to increase the strength without sacrificing too much of the lightness. Many different alloys have been devised and marketed, but two types are of outstanding importance, namely duralumin and the aluminium-silicon alloys. The former type consists of forging alloys, *i.e.*, they are rolled into sheets, strip, rods, etc. The latter are casting alloys, *i.e.*, they are used as casting in the form of pistons, crank cases, etc. Duralumin contains from 3.5-4.5 per cent of copper and small quantities of manganese and magnesium. When slowly cooled it is moderately soft, and its strength is not immediately affected by chilling, but after quenching in water from about 475°-500° C. its strength increases with time. This is known as "age-hardening" which is now recognized as an

extremely important phenomenon, not confined to this type of alloy. After quenching and age-hardening, duralumin is about four times as strong as aluminium and it is essential in the construction of modern aircraft.

The alloys of aluminium and silicon usually contain between 12 and 14 per cent of silicon, and as silicon is lighter than aluminium the alloys are slightly lighter than pure aluminium or any of its other alloys. Normally aluminium and silicon crystallize together from the molten state in the form of fairly large plates which give a metal with a coarse structure and a tendency to brittleness. It has been discovered that the addition of very small amounts of sodium—less than 0.1 per cent—produces a very fine structure, and the mechanical properties of the alloys treated in this way are remarkably good for cast light alloys. Further, these "modified" alloys, as they are called, make very sound castings, as compared with pure aluminium or duralumin, and during the last year or two it has been found that the soundness of all aluminium alloy castings can be greatly improved by treating the molten metal before casting with boron or titanium tetrachloride.

Tungsten, molybdenum and certain other metals cannot be extracted by the usual methods because of their extremely high melting points, and it is this property that determines the utility of these metals. Tungsten occurs in nature as an oxide, which is reduced by hydrogen at high temperatures and the metal is obtained in the form of a fine powder. This is compressed mechanically and a certain amount of cohesion between the particles results. The fragile rods of compressed powder are then heated to a very high temperature in an atmosphere of hydrogen and subjected to prolonged hammering in a swaging machine. Finally the rods are heated again to a very high temperature by passing an electric current through them. This brings about complete cohesion of the particles and the rods are then ready for drawing into wire for electric lamp filaments.

Besides the introduction of numerous new alloy steels and light alloys, the last twenty years have been marked by an extended application and improvement in the properties of the nickel-chromium and nickel-copper alloys. The former are conspicuous for their resistance to oxidation and their high strength at elevated temperatures, the latter for their strength, ductility, homogeneity and resistance to corrosion. As a result of scientific research great advances have also been made in the metallurgy of cast iron, and high tensile irons, corrosion-resisting irons, and growth-resisting irons are now made in large quantities. It is no longer customary to regard cast iron as a metal of poor mechanical properties but easy to cast. Strenuous and successful efforts are now being made to improve its mechanical qualities without sacrificing its casting properties.

New Light on the Ant-Eater.

A FOSSIL discovered in Wyoming, U.S.A., last summer has now been estimated as ten million years old. It belongs to the only known ancestral form of the African ant-eater and has been named *Tubulodon taylori* in honour of its discoverer, Mr. W. Z. Taylor of Princeton. Two jaws, parts of the skull, fragments of toe bones, and coprolites were all that remained of the skeleton. Near it were found remains of other animals, including a three-toed horse, a small type of monkey, lizards, alligators, ancestral armadillos, turtles and tapirs.

Dr. Jepsen, who has performed the work of identification, described the specimens to the American Philosophical Society last month. Identification was made in two ways—by the strange form of the teeth of ant-eaters, found in no other animal, and by a chemical analysis of the coprolites. The modern ant-eater's teeth are made up of parallel tubes instead of the customary nerve or pulp cavity, but in the embryo these curious animals have minute teeth of the more usual sort—an example of Haeckel's law that "the life history of the individual gives a brief resumé of the evolutionary history of the race."

This fact led a Swedish scientist to suggest, as long ago as 1906, that if the ancestral form of the ant-eater should ever be found, it would have teeth in maturity as well as in the embryo. In the jaw-bones discovered by Taylor there is confirmation for this prediction, for although the teeth of *Tubulodon taylori* are double-rooted and have a pulp cavity, the beginnings of the parallel tubes are clearly evident. The feeding habits of *Tubulodon* were determined by an analysis of the coprolites. This revealed that the strange creature had in its intestines a large amount of chitin, the material of which insect skeletons are composed.

The discovery was made in the course of investigations carried out by a party of Princeton geologists. The "Bad Lands" of Wyoming are a favourite resort for research, and every summer the university organizes expeditions to this area, where many interesting facts relating to pre-historic America have been brought to light.

Reptiles and Human Physiology.

By Francis G. Benedict.

Director of the Nutrition Laboratory, Carnegie Institution of Washington.

Recent research in human physiology at the Carnegie Institution of Washington includes an extensive study of cold-blooded animals. Experiments have been made on a number of reptiles and interesting results are announced.

THE almost universal feeling of repugnance for the snake persists even to-day, in spite of the fact that this animal now serves many useful purposes. Thus, certain snakes such as the gopher species are of real economic importance because of their activity in destroying rodents, and reptile skins are becoming more and more popular for footwear and leather goods. When we summon a physician to the house, we do not realize that the snake has indirectly contributed its small share to his learning. In order to diagnose our ailment correctly the physician must have knowledge first of all concerning the physiological processes that take place in the body when we are healthy.

Study of Diseases.

For this reason research laboratories were established, where physiologists have been trying to discover what are the normal reactions and the normal functions of man. Each individual organ and each anatomical part of the human body has been studied under normal conditions in an attempt to secure all the information possible about that function. The study of the diseased body, or the study of human pathology, has likewise been carried on as an indirect method of obtaining knowledge regarding normal human physiology. Thus, information regarding the abnormal liver of man in disease has proved of great value in securing more exact knowledge of the normal function of the liver.

Another indirect means of understanding the functions of the human body is the study of animal physiology. Many observations have been made with different animals, the object of most of which has been the ultimate perfection of knowledge regarding the physiology of our own bodies. In some animals the particular organ or function in which the medical man or scientist may be interested is especially elaborated. The digestive organs of the ruminant, for instance, are so elaborate that the food remains in the alimentary tract for a much longer time than is the case with man. The longer retention of food results in fermentations and chemical reactions, the study of which helps in interpreting certain digestive processes in man.

In studying animals to clarify the problems encountered with human beings, scientists recognized years ago the value of including cold-blooded animals. It has been found that the best indications as to whether our body is functioning normally are heat production and body temperature. The amount of heat that we produce and our body temperature show whether our vital activity or life processes are at a normal or an abnormal level. To aid in the interpretation of the abnormally high temperature of man during fever, it was early thought expedient by investigators to note the effect of rapidly changing body temperatures in the case of cold-blooded animals. The body temperature of the cold-blooded animal changes with the temperature of the air surrounding it.

How do these changes in the body temperature of the cold-blooded animal affect its body and how can a study of the changes aid in understanding the cause and results of fever in man? These are questions typical of those that are continually presenting themselves to the physician and research worker. Some of them have now been answered. Others remain yet to be solved. But there is no doubt that the study of animal physiology is necessary for the best understanding of human physiology.

In 1907 the Nutrition Laboratory was established in Boston by the Carnegie Institution of Washington for the study of problems in human and animal nutrition. Since its establishment, the Laboratory has undertaken an extensive programme of research on heat production and thermal relationships, not only with human beings but with a large number of other warm-blooded animals ranging in size from a horse to a mouse. In the furtherance of this programme the heat production of cold-blooded animals under various conditions has also been studied.

Experiments on Snakes.

The first experiments carried out by the Nutrition Laboratory with cold-blooded animals began in 1915 at the New York Zoological Park, and continued over a period of seventeen years. Nearly one thousand observations were made, chiefly with snakes, but also with a number of lizards, alligators, and giant tortoises. Thirty-six snakes were used which varied in size from

a five-pound gopher snake to a seventeen-foot reticulated python of seventy pounds. The python had to be held by five men in order to obtain measurements of its length and body girths.

The main object of our study with these animals was to measure the heat production and the body temperature under various conditions, and to compare the results with similar observations on human beings and other warm-blooded animals. Many other observations were made regarding changes in body weight, the heart rate, the respiration rate, the water vaporized from the body and the composition of the urine and feces. Since it was known from previous experimental work that the heat production can be most readily determined not by direct measurement but by indirect measurement of the products of respiration, an apparatus was installed in the reptile house of the New York Zoological Park in which the carbon dioxide exhaled and the oxygen absorbed by the snake or other reptile could be accurately measured during a definite period of time.

In addition to the study of the heat production, another problem was to establish the relationship between the body temperature and the environmental temperature of these animals. It would seem simple to establish this relationship but, as a matter of fact, it proved to be most difficult. The temperature of the animal itself could be accurately determined by noting the temperature in the mouth or the cloaca, but the exact temperature of the air surrounding the animal was not so easily found. For this reason mercurial thermometers were not used in our most exact studies, but instead a sensitive electric device, whereby the temperature of the skin of the snake and the temperature of the air around the snake could be recorded within a few seconds. A "thermo-junction" or electric thermometer is connected by wires to a galvanometer in the room outside the snake's den. The electric thermometer is carefully placed between the folds of the snake, and the temperature of the skin at that spot instantly recorded on the apparatus outside.

TAKING THE TEMPERATURE.

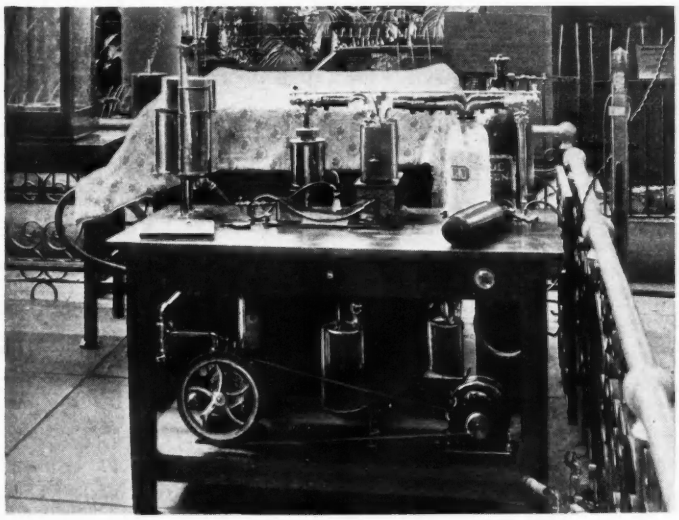
The instrument used for measuring the skin temperature, which is described in the text. In this case the snake was an incubating python.

The accompanying photograph shows the apparatus used in taking the skin temperature of the snakes. The snake, an incubating python, was placed during the observations, and the measurements were not affected by irritability or muscular activity, which in themselves would have increased her temperature. Many of the snakes are highly irritable and dangerous to handle. A few seconds after one of the photographs had been taken, a huge python lunged at an observer at the front of the den, striking its head against the glass but fortunately missing the man.

The body temperature of man and practically all warm-blooded animals remains essentially constant under normal conditions, regardless of what the environmental temperature may be. In the cold weather of the Arctic zone, for example, the body temperature of the warm-blooded animal is no lower than it is in the temperate zone or the tropics. Indeed, the polar fox is known to have a body temperature even higher than that of man. The temperature of the cold-blooded animal, on the other hand, is affected by the temperature of its surroundings. Thus, the Nutrition Laboratory found that the body or the cell temperature of the snake changes with almost mathematical regularity with the changes in room temperature. It has been supposed that the cold-blooded animal has a temperature a little above its environment, but our observations prove conclusively that the temperature of the snake is usually a little below that of the environment.

It was also found that the snake loses a great deal of water from its

skin and lungs. The water, in vapourizing, absorbs heat. The total amount of heat produced by the snake is usually so small that all of it is lost in the vapourization of water. In many instances heat may be absorbed by the animal from the environment, as it suns itself. This absorbed heat serves to vapourize still more water. Under normal circumstances the quiet snake, not in active digestion, will have a temperature only a degree below the average temperature of the environment. At the peak of digestion there may be a slight elevation of its temperature. If the snake is agitated or has been extremely active, its temperature may be 9° or 10° F. above the temperature of the environment, but within a few hours will fall to the temperature of the environment or somewhat below it.



HEAT PRODUCTION IN SNAKES.

The snake is placed in an air-tight chamber, which is covered by a quilt. The increase in weight of the reagent bottles show the amount of carbon dioxide exhaled.

One of the most interesting features of our temperature study was with an incubating snake. The majority of snakes are viviparous, some are oviparous, and of these one is known to cover her eggs with her body. It has long been a matter of debate as to whether this covering of the eggs by the mother snake is primarily to protect the eggs or to aid in the incubation. In April, 1931, a South African python laid twenty eggs at the National Zoological Park in Washington, coiled about them in the characteristic manner, and remained there for approximately sixty days. Unfortunately the eggs were not fertile and hence did not hatch. The Nutrition Laboratory was privileged to study the skin temperature of this animal while she was on her eggs.

Extreme care was taken to establish the true temperature of the air surrounding the snake, indeed, even greater care than was taken to note the temperature of the snake itself. It was clearly demonstrated that the body temperature of this snake was on the whole about 7° F. above that of the air surrounding her. The snake was placid and tractable during the observations, and hence the measurements were uncontaminated by any irritability, excitation, or muscular activity, which of themselves would increase her temperature. It thus appears clear that this snake's temperature actually was above that of the environment, and seemingly she was producing heat to keep her eggs warm.

The accompanying photograph shows the apparatus used by the Nutrition Laboratory to study the heat production of snakes. The snake is placed in an air-tight, well ventilated box, shown behind the table, covered with a quilt. The blower under the table draws the air from the chamber, passes it through the reagent bottles on top of the table, where the carbon dioxide and water vapour eliminated by the snake are removed from the air, and returns it to the chamber, enriched with oxygen to replace that used by the snake. The increases in weight of the various reagent bottles (which are weighed on the balance in the rear) show the amount of carbon dioxide exhaled and water vapour eliminated by the animal.

The cold-blooded animal's body temperature and heat production increase and decrease with the rise and fall of the temperature of the air around it. For the most part the cold-blooded animal is quiet in comparison with the warm-blooded animal. At low temperatures especially it engages in little muscular activity, and its vital activity is at a very low level. During periods of dormancy or hibernation its heat production reaches an almost immeasurably low level. It therefore needs very little food, compared with the warm-blooded animal. Yet the large serpents often eat an enormous meal at one time. Thus, during our study a seventy-pound python ate a twenty-pound pig. In other words, at one meal it ate four hundred times its daily energy needs, enough to last a year.

In the wild the snake travels a relatively short

distance to some water hole, where it waits until its prey comes along. The attack is immediate, and for perhaps twenty minutes the activity is vigorous. At the end of this time the prey has usually not only been killed but is completely swallowed. The snake now has enough food to meet its need for possibly several months, and has used up very little energy in obtaining it. With no other animals in the world, certainly among the vertebrates, can one expect such economy in the securing of food. In view of this economy in energy expenditure, one can easily understand why it is possible for a large snake to exist for a year or longer without food.

New Observations.

With warm-blooded animals it has been found that, in general, the larger the animal the larger the total heat production. This relationship, however, is not directly proportional to the size of the animal. Thus, a dog weighing twice as much as another dog will not produce twice the amount of heat; nor will a bird three times as large as another produce three times as much heat. It was thought many years ago that the production of heat is determined by the possibility for losing heat, that is, by the surface area of the animal. Therefore, it was believed that the heat production is proportional to the surface area and that all animals produce the same amount of heat per unit of surface area. With the warm-blooded animals studied by the Nutrition Laboratory it was quickly found that this is not true, but that there is a considerable difference in the heat production per unit of surface area.

Among the cold-blooded animals, as is to be expected, the larger animals also produce the greater amount of heat. But here again the total heat production is not directly proportional to the body weight, for the smaller animals (as with the smaller warm-blooded animals) produce a larger amount of heat per unit of weight than do the larger animals. On the other hand, the heat production per unit of surface area was for all the cold-blooded animals that we studied, other than the tortoise, reasonably constant at a constant temperature. In such comparisons with cold-blooded animals the temperature has to be taken into consideration as well as differences in surface area, because the heat production varies with the changes in temperature.

The above comparisons are perhaps of more special interest to the physiologist than to the general reader. We are more particularly concerned in learning how observations on the snake, the lizard, the alligator, or the tortoise can help to solve the problems that are found in human physiology. For this purpose we must compare the cold-blooded with the warm-blooded animal, preferably choosing two animals of the same weight. How does the heat production of two such animals of the same weight compare?

In order to make such a comparison both animals must have the same body temperature. It is practically impossible to lower very much the temperature of the warm-blooded animals under normal conditions. Only those animals that hibernate have a variable temperature, and such animals are difficult to secure for study. On the other hand, it is possible to warm the body of certain cold-blooded animals, especially the tropical animals, so that their cell temperature will be essentially that of the warm-blooded animal, that is, about 98.6° F. This was done with a number of snakes, both small and large, and it was found that the cold-blooded animal, even at the same temperature and weight as the warm-blooded animal, cannot produce the same amount of heat that the warm-blooded organism produces.

The Nutrition Laboratory has found that the mouse, for example, one of the smallest mammals, produces 640 calories for each square metre of its surface area under normal conditions, without muscular activity, and at an environmental temperature of 82° F. The snake, on the contrary, even when it has the same body temperature as the mouse, can produce at the most only about 100 calories for each square metre of surface area. There is thus a tremendous difference in the thermal relationships shown by these two types of animal.

In this gap between cold-blooded and warm-blooded animals three striking intermediary steps have been noted, further study of which will probably throw much light upon the pronounced differences between cold-blooded and warm-blooded animals. The female python, for instance, has a body temperature actually higher than its environment during the incubation period. It will be interesting to determine what its heat production is during this period and whether it approximates to that of warm-blooded animals any more closely than does that of the non-incubating snake.

Studying Tortoises.

The tortoises also furnish a field for further study. They have a much higher heat production for each square metre of surface area than have the snakes, alligators, and lizards. They also have a much richer blood supply than these other cold-blooded creatures, but even then the blood supply of the tortoise is too feeble to enable it to produce heat at

the same rate as the warm-blooded animal. Nevertheless, it can produce more heat than the snake, lizard, and alligator, and hence may be considered to occupy an intermediary stage between these animals and the warm-blooded.

The hibernating animal likewise represents an intermediary stage. During hibernation the warm-blooded animal's body temperature and vital activity are greatly lowered. Indeed, the body temperature of a hibernating warm-blooded animal may easily be the same as that of the snake, alligator, or fish, for its temperature will fall with that of the environment nearly down to the freezing point of water without resulting in the death of the animal. It is therefore possible to compare the heat production of a hibernating marmot, for example, with that of a lizard of the same body weight and temperature.

A study with hibernating wood-chucks is now in progress at the Nutrition Laboratory, but is not yet completed. Thus far the results are in full harmony with several studies of this type by other investigators, who have shown that the marmot even at the same cell temperature as the snake has a much higher heat production. Here again the animal having the richer blood supply and better blood distribution has the larger heat production and is living at a higher level of vital activity, even though its body temperature is greatly depressed. Such variations in body temperature as are found with the hibernating marmot and with the snake, alligator, and lizard in the normal course of their existence are not found with humans.

A certain amount of fluctuation in the body temperature of humans does take place, however, especially under the abnormal conditions resulting in fever. Therefore it is of direct value, in interpreting the laws governing the heat production and heat loss of humans, to study animals showing such marked changes in heat production and body temperature as the incubating python, the red-fleshed tortoise, and the hibernating marmot. When such studies are completed, we may hope to be able to solve some of the still unanswered problems in human physiology.

Plants and Evolution.

SINCE the "Origin of Species" was published more than seventy years ago, evolutionists have learnt much from plants. But there has been comparatively little advance towards an agreed view on the relationship of the various classes and groups of plants and their respective lines of evolution.

In a delightful little book on "Plants" (Cambridge University Press, 4*s*. 6*d*.), Professor A. C. Seward confesses that we have still touched only the fringe of the curtain which hides the mystery of life. Words written by Seneca more than nineteen centuries ago are still true: "We imagine that we are initiated into the mysteries of nature, but we are still hanging about her outer courts." But what distinguishes our researches to-day is that botanists are more conscious of the difficulties of the enquiry into evolution than they were in the time of Darwin.

Professor Seward points out that one of the most puzzling questions for botanists is the relation to one another of the larger divisions of the plant kingdom. It used to be a common practice to represent the various groups as so many different branches of one genealogical tree, thus implying a direct relationship between one group and another.

In recent years the tendency has been to represent the progress of development during the history of the earth as a series of more or less independent lines, rather than as a number of divergent branches meeting in one common stem. It is probably more in accordance with fact to represent evolution as many disconnected lines, each starting from a separate source, than to think of it in terms of a single tree with many branches from one original trunk.

"The whole panorama of the world as we see it," Professor Seward concludes, "with its teeming multitudes of plants and animals, the rocky crust rising into folded mountain-chains, covered with the sand of deserts or hidden by tropical forests, with its rivers, seas and oceans, is but one scene in a drama extending over hundreds of millions of years. In the crust of the earth are entombed fragmentary remains of a mere fraction of the hosts which occupied the stage in the successive ages of the world, each stage having its own scenery differing in a greater or less degree from that of the age in which we live. The ambition of the evolutionist is to reconstruct within the narrow limits that are possible the development of plant-life, a development by no means uniformly progressive but frequently retrogressive.

"The province of the student of evolution is the whole world, the world as it is and as it was; his aim can never be more than partially achieved, he can never hope to reach his goal; but he can derive pleasure from his search for origins which will enable him to see the present face of the earth with an understanding and an enchantment intensified and illumined by a knowledge of the past."

Progress of the Geological Survey.

By W. W. Watts, F.R.S.

Emeritus Professor of Geology, Imperial College of Science.

For a hundred years this country has led the world in geological research. The new museum in London will provide even wider facilities for study and for exhibiting to the public the material lately collected. Professor Watts traces the progress of the Geological Survey since its modest inception in 1835.

A CENTURY has now elapsed since Henry Thomas De la Beche asked, and was granted, permission "to affix geological colours to the (ordnance) maps of Devonshire and portions of Somerset, Dorset and Cornwall." Very considerable advance in this task was made by 1835, when a continuation was officially taken in hand by the Ordnance Survey and De la Beche appointed at £300 a year to extend it to other ordnance maps. In a small way a definite geological survey of the country was thus started. By 1839 De la Beche had obtained Government sanction to the establishment of a Museum of specimens collected by the survey and by other means, and in 1841 the collections were housed in a building at Craig's Court under the Office of Woods and Forests.

A laboratory was established here, a mining record office set up, and authority obtained, though not yet exercised, for the delivery of lectures. Five years later the Geological Survey was transferred to the Office of Woods, Forests, Works, etc., and joined up with the Museum and with the Geological Survey of Ireland. The new Museum of Practical Geology in Jermyn Street was opened by the Prince Consort in 1851, and De la Beche was able to complete his scheme by starting there a School of Mines for the technical and scientific training of geologists, miners, and metallurgists, and for other educational work, including lectures to artisans.

ANTICLINE IN COAL MEASURES.

A view in Pembrokeshire. All the photographs are from the Geological Survey series and are reproduced by permission of the Controller, H.M. Stationery Office.

Thus De la Beche saw the realization of his chief ideals: the survey and record of the nature and distribution of the mineral wealth of the country; a library, offices, and laboratories for the investigation of the nature and uses of these materials; a museum to contain the collections on which the survey was based, to illustrate the mineral wealth of the country and its industrial application, and to form a standard of reference to guide the extension of geological and mining knowledge at home and overseas; a record of the exploitation of mineral wealth to register the stages reached in working and so save waste by the guidance of further exploitation and new development; a school to train experts in the search for and in the survey, examination, and utilization of mineral wealth. Of these institutions two have "budded off." The Mining Record Office has become a separate institution. The Royal School of Mines has, by modification and amalgamation, passed into the great school for technological and scientific training and research known as the Imperial College.

Although the field-work of the Geological Survey of Ireland has from the beginning been executed on the scale of six inches to the mile, the scale used for England for the primary survey was one mile to the inch; and when it is realized that the only available map was not contoured, and that the detail was often obscured by heavy hill-shading, we are filled with admiration for the accuracy and beauty of the mapping and for the wonderful "eye for a country" and a map, that the early surveyors must have possessed. When, however, the full advantage of the six inch maps was realized, the primary survey on the smaller scale was stopped and all new work as well as revision of that already published was conducted on the larger scale. For publication, as large a selection of the recorded information as the smaller scales will carry is issued on the standard scale of one inch, and with further

selection and reduction, on the ½ inch scale of the "index map" and the 1/25 scale of the general map of the British Isles. The "old series" maps were coloured by hand as the demand was restricted and so the price was high. The "new series" is now entirely colour-printed at the Ordnance Offices at Southampton and is not only cheaper but more uniform in accuracy.

The original field maps and "clean copies" of them are preserved at the office. They are available for reference and to supply answers to enquiries; and photographic copies showing the lines, or hand coloured copies of the maps can be supplied. Where detailed information is demanded, as in mining areas or the neighbourhood of large towns, or where the structures depicted are typical, novel, or of highly complicated character, maps on the six inch scale have been published and have proved of great value to students and for industrial use.

EROSION BY THE SEA.

A photograph of Stair Hole, Dorsetshire, which is a striking example of a fold in secondary rocks, determining erosion by the sea and the weather.

The Survey staff, apart from specialists and experts at headquarters who only visit the field for duties of inspection or special enquiry, is divided into a number of units, each in charge of a definite area. South-eastern England, the Midlands, Yorkshire, Lancashire, Northumbria, and Cumbria, for instance, have each their unit under the charge of a "district geologist." The last unit was formerly quartered at Whitehaven, and the three foregoing ones are still located at York, Manchester, and Newcastle. This decentralization is useful, particularly in providing an office for local information, but the winter meeting with the rest of the staff in London and the pooling and discussion of information, has also great advantages.

It might be thought that, once the position of rock-masses in the earth-crust had been determined and laid down on maps, there could be no need for further revision. It has to be remembered, however, that a map is not so much an expression of fact as of knowledge of fact, and that as a geological map depends on exposures of rocks and their mutual relations, its accuracy improves as their number increases. Thus all new developments, mines, quarries, cuttings, foundations, wells, borings, coast-erosion, even ditches, give new facts and lead to closer approximation to the truth. They must all be watched and recorded, and used in checking and improving the accuracy of the map. The bulk of such information, even that of a confidential nature, finds its way to Jermyn Street, where it is recorded and indexed, and when released, added to the stock of geological knowledge.

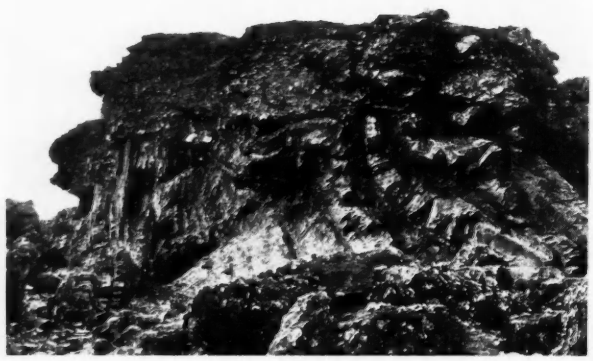
Further, the value of the map is not only in its representation of the distribution of rock-types at the surface, but even more as the expression of rock-relation and structure in the solid crust itself. Correct and complete knowledge of this is not only a scientific desideratum; it spells the difference between success and failure in mining operations. Such knowledge is vital, for instance, in the coalfields and other mining areas; and it is these which have been revised in the first instance, a task rapidly approaching completion. Again on the larger scales more detailed sub-division is possible, producing more accurate classification and correlation, a matter of economic as well as scientific value, particularly in the correct interpretation of borings and sinkings, essential, not only in the "exposed" but still more in the "concealed" coal-fields into which working is now being extended.

Revision cannot be confined to areas of immediate economic significance. Older and younger rocks are present in the same areas and must be dealt with, though under obvious disadvantages, before revised sheets can be published. The mapping of such rocks, apart from the fact that it is never possible to predict what rocks or structures may be of consequence in the future, often leads to the elucidation of new structures and new principles which may at any moment prove of vital consequence in their application to deposits of economic value.

New methods of investigation as well as new requirements are being developed, and within a staff of men of high scientific training there exists the means of testing these out under ideal conditions before they are taken over by industrialists, often at heavy

cost. Thus the new geophysical methods of prospecting, gravitational, magnetic, electric, seismic, have been or will be submitted to crucial tests under proper controls, their special applicability, their reliability, and their limitations ascertained.

The Survey has always given attention to the superficial deposits which mask the more "solid" rocks of the crust, and constitute the link between the latter and the soil. These accumulations are now shown on the normal maps, or on a "drift" edition separately published. For questions of planning and siting, foundation and sanitation, for building and especially for large works, for agriculture and forestry, and for the scientific study of habitat and ecology, such maps are of more use than the "solid edition." So much is this the case that co-operation of the geologists is now being sought and given in the preparation of soil maps by agricultural specialists.



AN UNCONFORMABLE JUNCTION.
Breccia of Lower Old Red Sandstone age with cleaved limestones and slates, at Kerrera, Oban, Argyllshire.

The value of photography as an aid in the registration of geological facts has long been recognized, and for nearly half a century the Survey has made use of the method. A large collection of negatives taken under the supervision of the field staff has been made, descriptive accounts have been published, and the whole collection stored and displayed at the office. These are not only of service in the illustration of memoirs, but they give new life to museum exhibits, keep a record of features and phenomena that may be of a transitory nature, and provide material which has proved of the utmost value in the teaching of geolgogy and geography, while they are also of use in such problems as coast-erosion and defence. By the permission of the Controller of the Stationery Office we reproduce some typical examples chosen from this collection, two illustrating unconformity in Scotland, two showing folding in English rocks, and one of the latter pair showing marine and weather erosion guided by rock strength and structure.

The resident staff, supported by the field officers when present at headquarters, functions as a bureau of information which is freely used by all classes of technical enquirer; and the Survey endeavours to live up to the precept of one of its famous members that no enquirer should be allowed to depart without obtaining some information. The interpretation of maps, sections and memoirs, information with reference to coal, iron, fireclay, building- and road-stones, sites and foundations, problems of wells, springs, and drainage, mining queries, routes of roads and railways, tunnels and cuttings, the interpretation of borings, are but a few of the lines of enquiry constantly cropping up. Further, it is not unusual for officers to go beyond the strict letter of their duties in guiding students and research workers in the determination of crucial and difficult fossils, minerals, and rocks.

While the delineation of rock occurrences and structures on maps must always be the primary object of a geological survey, it is necessary to supplement this in various ways; especially as the results are to be used by others than those technically trained to extract from a map all the information it is capable of conveying. The structure of the country is depicted by the publication of "horizontal" sections drawn to show the position, nature, and arrangement of rocks to a considerable depth below ground, and taken along crucial directions across country. Where it is needful to know in greater detail the exact succession of rock types, in the coal-fields for instance, "vertical sections" on a still larger scale are issued, the strata being shown as they would occur in a shaft or well bored at right angles to their surfaces.

Equally important is the issue of printed descriptions of the districts mapped. At first large areas were grouped together, as, for instance, in Ramsay's North Wales, Topley's Weald, Judd's Rutland, Green's Yorkshire Coalfield, and Whitaker's London Basin. But it has been found possible to issue independent memoirs to accompany each map-sheet as published, and this is now the invariable practice. In these, as well as general and detailed accounts of the geology, there are chapters on the physiography and economics of the area in which the intimate knowledge of the

surveyor is of special service, and appendices recording statistics in relation to such subjects as wells, borings, mines, etc. There are also photographic and other illustrations, sections, and often maps of parts or the whole area.

But it is still essential to group the information under headings which may be either geographical or geological. Thus each coalfield or mining area is described in a single memoir or in a series, and these are kept up-to-date by the insertion of fresh information as it comes to hand into new editions. Among geographical groups may be mentioned the memoirs on Mull, Skye, the Isle of Man, and the North-west Highlands ; and among geological ones those on the Silurian Rocks, and on the Jurassic and the Cretaceous Rocks of England. These summarize vast amounts of information and are veritable text-books of great value to students and investigators, both within and without the country.

MOUNTAIN OF LEWISIAN GNEISS.
Partly buried under Torridon Sandstone which is seen to abut against its steep side. Slioch and Meall East, Ross-shire.

The demands of town-planners and water engineers for information with regard to the nature and distribution of underground water has been met by the publication of a series of water-supply memoirs grouped under county headings. During the war and since, it has been found advisable to summarize old and to collect new information with reference to the mineral resources of the country, and over thirty memoirs on these topics have been issued. Only brief reference can be made to other publications such as palaeontological descriptive memoirs, museum handbooks to collections, models, etc., and the annual summary report, of which a special part is now reserved for short communications by Survey Officers on their current discoveries.

In selecting areas for revision and separate description the needs of students and investigators have not been lost sight of, and memoirs have been published dealing with the neighbourhood of university towns, popular and holiday resorts, and regions like the Isle of Wight, Hastings, Ardnamurchan, presenting special advantages to the student in search of field experience.

While the design and planning of the Jermyn Street Museum of Practical Geology was admirable for its date and the purposes then in sight, it has not proved elastic enough to evolve in tune with modern requirements. The object was to get together and display (for the first time) the mineral materials of the country in their natural relations, and especially to bring out their utilitarian applications. Consequently, while there was abundant space for display, there was too little storage and study accommodation. Even the addition of neighbouring premises, the removal of the elaborate application—collections, porcelain, pottery, metals and alloys, jewels, etc., and the shifting of the teaching function, did not provide for expansion and the rapid and ready access to materials for study and research. The design of the new museum at South Kensington, while providing not less facilities for interesting and attracting the intelligent visitor, catering for the " popular " side of the subject, and equally illustrating the geology of Britain and the dependence of industry on mineral resources, will offer far better opportunities for research by workers, whether members of staff or those coming from outside ; and at the same time provide ready access to the vast amount of material which should be at hand to meet the innumerable enquiries of those in search of scientific or economic information.

While a judicious selection will be made from material which has already been exhibited, it is intended to supplement this with much new material collected for the purpose, and to illustrate the display with photographs of characteristic landscapes, with maps, models, diagrams and sections of the actual phenomena, and with views and paintings intended to restore and present in vivid form scenes from past geological periods, the evidence for which exists in the studies and collections of the geological surveyors.

So far as planning is concerned it is proposed to devote the main floor of the museum to the illustration of the main principles of geology and some of the more striking applications of the science. The methods

by which rocks are formed, deformed, and re-formed; their sculpture by weathering and erosion to form characteristic landscapes; the fossil relics of extinct animals and plants; and some of the rarer and more beautiful rocks and minerals, such as marbles and precious stones; will be exhibited here, in association with maps, models and photographs. Here, too, it may be possible to show examples of the new work of the Survey and to mark its progress.

Geological Units.

The first gallery will develop very fully a method already tried in the Scottish and Irish Museums. The country will be divided into a number of districts, each forming a simple and natural geological unit. Old materials and new specimens collected *ad hoc* in the form of minerals, rocks and fossils, will be displayed; and diagrams, models, maps and photographs will be supplied or adapted to illustrate the features and phenomena that are on too large a scale to be adequately represented by specimens. Again, modifying the practice adopted by De la Beche, Ramsay, and their successors, explanatory handbooks will be issued to supplement the labelling of exhibits and to increase the educational value of the display to students and other visitors.

The second gallery will be devoted to the practical and industrial applications of geology, and will deal with such subjects as coals, oils, ores, building, ornamental and precious stones, clays and shales, cements, sands, refractories, abrasives, and the host of valuable materials derived and utilized by man from the earth's crust. The bulk of this will be British and will illustrate especially the great series of "Resources Memoirs"; but, as elsewhere in the museum, when a home product is lacking, it will be necessary to draw it from overseas.

The wide area of the top floor will contain all the best material not otherwise exhibited, the great stores on which the conclusions expressed in maps and memoirs are founded, and also collected material already investigated, in the course of investigation, or awaiting study. These collections, while mainly intended for research by officers of the Survey and Museum and the specialists employed in the service, will also be available to visiting geologists and will form the basis on which replies to enquirers, technical or scientific, will be based. It will form, with the display in the first gallery, a standard of reference to the historical geology of the country, a complement to the history of life as displayed in the Natural History Museum close by, and a centre of research in which full facilities can be given for the study of material, largely unique and irreplaceable, which has accumulated during a century of out-door work.

It is too early to judge from the character of the "steel cage" what appearance will be presented by the new museum, but it may be inferred that it will conform in external features and internal convenience with its neighbour, the Science Museum, and will be a fitting climax to a century's successful work. One detail of the old museum will probably not be preserved, the use of illustrative examples of various British ornamental and building-stones in the fabric. At the present day it is far more important that such examples should form part of the collections, and should be exhibited in such a way that study and investigation are easily possible; and that the architect should provide sufficient space and good lighting to bring out their individuality and beauty.

The library, which has always been open to the public, will also be situated here. Specialists will suffer to some extent by the greater distance from the great library of the Geological Society at Burlington House, which has always placed its resources at the disposal of the Survey Officers and enquirers at Jermyn Street. But they will gain by the proximity of the Government Science Library at present housed in the building of the Imperial College, which may be regarded as the complement of the survey library, containing many serials not present in the latter. The unique feature of the survey library, its magnificent series of geological maps which has been gathered and carefully stored from the beginning, will be kept up and will maintain its reputation as probably the finest collection extant.

Steady Progress.

In conclusion, it may be stated that the career of the Geological Survey for nearly a hundred years has been one of steady progress, improvement and evolution. Such of its undertakings as were self-centred have branched off or become allied with kindred institutions, but the museum on its new site can more than make up for any former loss of contact by the facilities it will be able to give to their students and research workers. The main issues, first, the production of accurate maps and memoirs, with the auxiliary services, secondly, the preservation and study of evidence and, thirdly, the exhibition, to students and to the public, of mineral resources and their applications, have stood together and must so stand as long as the country has mineral resources and use for them, and as long as it desires to hold the place in the forefront of geological research which it attained a century ago.

Embryology: Exact or Inexact?

By Joseph Needham.

University Demonstrator in Biochemistry, Cambridge.

In the March issue of DISCOVERY *Professor E. W. MacBride discussed an important new book by Dr. Needham on chemical embryology. In the following article the author takes issue with his critic and refutes the suggestion that the chemical analysis of embryos is "an example of exact methods applied to inexact data."*

PROFESSOR MACBRIDE'S account of my book "Chemical Embryology" in the March issue of *Discovery* makes it necessary for me to come to the defence of the positions which he there attacks. His arguments contain so many of the usual fallacies employed by writers who, for one reason or another, resent the application of physico-chemical methods to living organisms, that it is worth while to examine them.

Faced by a great new body of knowledge allied to our own, two courses are open to us. We can either welcome it as an additional illumination of our problems, or we can dismiss it by saying that it contains nothing of importance for our subject. Whatever the merits of the first of these two courses, the second has the supreme merit that it avoids the necessity of revising any of our favourite opinions, and economizes intellectual effort—the first (and last) law of Hypnodynamics. There is a not unfamiliar type of don who remarks of the University library that it is indeed a very big place, an overwhelming collection of books, but after all, ninety-five per cent of it is rubbish, not worth the looking into. Such simple protective mechanisms no doubt account for the repugnance which Professor MacBride exhibits to constructive thinking in embryology.

Progress of Biochemistry.

His primary objection to biochemistry in general and to chemical embryology in particular appears to be that the biochemist is condemned to the study of dead protoplasm and can never envisage the living cell at all in his calculations. "Chemical Embryology," says Professor MacBride, "is a storehouse of all that is known about the chemical products of the dead bodies of embryos" (page 94). Or again, "The emanations from the living nuclei" (whatever they may be) "will not be discoverable by the chemical analysis of the dead egg" (page 97). Thus biochemistry is always mere *thanatology*, always the analysis of something that inevitably died before the analysis was begun. Fifty years ago when the phrase *Tierchemie ist nur Schmierchemie* was current, there might have been some justification (though not much then) for this point of view. But nothing has been more characteristic of the progress of biochemistry during the last half-century than the steadily increasing refinement of its analytical methods—a process which may have escaped Professor MacBride's attention but which is none the less relevant to his theme. Biochemists have been able more and more to employ methods which do little or no harm to the living material.

The Living Cell.

The study of the living cell itself has made great strides. Is the vast amount of biochemical information which we obtain from respiratory and calorimetric experiments to be regarded as the analysis of dead protoplasm? Is the study of growth-rates and the effect of temperature and other factors on growth-rates to be discarded as thanatological? Does the analysis of food-materials and end-products of excretion involve the destruction of the experimental animal? Biochemical conclusions of wide significance were reached by Glaser, who caused his protozoa no greater inconvenience than that of being made to swim a measured course under the microscope at different temperatures.

Micro-electrodes of various kinds may be employed with single cells, and Seifriz determined protoplasmic viscosity by means of an exceedingly minute metal ball introduced into a single cell and then attracted by an electromagnet. Again, by the micro-injection of indicators into the living cell, valuable information regarding hydrogen-ion concentration and oxidation-reduction potential may be gained; normal development subsequently (in the case of the egg) demonstrating the lack of injury to the cell (Needham & Needham; Chambers). Better still, spectrophotometric observations on living cells afford us information about the functions of cell-constituents obtainable in no other way. Such observations have been made by Vlès on the pigment and intra-cellular pH of echinoderm eggs, by Keilin on the universally important oxidative catalyst, cytochrome, and by Warburg in brilliant experiments on the principal respiratory enzyme.

Another line of argument would take its origin from the many experiments which biochemists have made involving successive samplings of living material.

If, for instance, the non-protein nitrogen of the blood of a pregnant mammal be raised artificially by injection, and the non-protein nitrogen then estimated at successive intervals of time in the foetal circulations, one foetus being removed for each determination, an ascending curve is obtained, all the constituent points being in agreement with one another. This could not be the case if some special thanatological process was intervening to upset the results. Again, it has been very striking to observe how closely the observations on muscular exercise in man have fitted in with the knowledge of the chemistry of muscular contraction. Here the correspondence has often been quantitative, not merely qualitative.

Dead Cells No Monopoly.

At all points, then, the direct chemical analysis of the killed cell links up with physico-chemical observations on the living cell, and Professor MacBride can only consider biochemistry as mere thanatology by persisting in an invincible ignorance of the subject. I foresee that he will *define* biochemistry as the study of dead bodies and their products. In this case, no more need be said; against the manipulator of definitions, the gods themselves fight in vain. But let us take (as a piece of exact embryology) the chapters of my book in order to discover what parts of it are concerned exclusively with the analysis of dead embryos. From this the sections on growth and differentiation are free (220 pages), as are those on respiration and heat-production (250 pages), while in the later part of the book, work on excretory products, hormones, the placental barrier, the quantitative resistance and susceptibility of embryos, etc., amounts to at least 270 pages. Out of a total of 1,424 pages, then, approximately 740 or 52 per cent can under no circumstances be said to be concerned with the chemical analysis of dead eggs and embryos. Only a very inexact embryologist could have described the contents of the book, other than such analyses, as the "results of experiments on living embryos by solutions of various metallic salts."

Professor MacBride's position on the matter of biology and thanatology is peculiarly surprising in view of the constant use which comparative morphological embryologists make of the methods of fixing, section-cutting, embedding in paraffin wax or celloidin, staining, and the like. Yet who does not know of the criticism which has been levelled at these methods on account of the delusive artifacts which they may produce? We think none the worse of morphological and cytological embryology for this, but to ignore these facts seems disingenuous, not to say jesuitical. Indeed, I find that of the illustrations in Professor MacBride's "Textbook of Invertebrate Embryology," 9 per cent are diagrams, 44 per cent drawings of living embryos, and 47 per cent drawings of sections, etc., *i.e.*, of *dead* ones. The study of dead cells is no monopoly of biochemistry.

As for the nature of living protoplasm, Professor MacBride's reference to the "foam" theory of Bütschli is singularly unhappy. It is true that the crude statements of the theory could not be accepted now, but it nevertheless remains also historically true that Bütschli's recognition of the essentially heterogeneous character of protoplasm opened the way for all the modern applications of colloidal physics and colloidal chemistry to the living cell. Sir F. G. Hopkins' definition, "Life is a dynamic equilibrium in a polyphasic system," embodies a profound insight into the affairs of the cell, and the nature of this equilibrium will be elucidated by detailed experimentation rather than by the *a priori* defeatism advocated by Professor MacBride. Professor MacBride's objection to the study of the egg as a physico-chemical system is so strong, apparently, as to lead him to attribute to me (by putting it in inverted commas) the phrase "physico-mechanical system"—a delightfully eighteenth-century doctrinaire idiom, originating, unfortunately, entirely in Professor MacBride's imagination.

Vitalistic Vagueness.

Professor MacBride's own views on the most important aspects of embryology at the present time are in the best vitalistic tradition of vagueness. He emphasizes the value of the experimental embryology of Spemann's school, but in explanation of organizer phenomena can only adduce "emanations from the living nuclei" together with a reference to the appearance of haemoglobin in the herring egg, which has nothing to do with the subject. According to Professor MacBride, I "dismiss Spemann's wonderful results on organizers in a sentence or two." My sentences must be remarkably long if they extend from p. 541 to p. 606 and occupy a considerable part of the Epilegomena. Now all embryologists must admit that Spemann's results and those of his collaborators have an importance that can hardly be over-estimated, but Professor MacBride is guilty of an elementary methodological error if he supposes that they can be explained by an appeal to mysterious emanations from the nuclei of the cells in the organizer region. The medicine is worse than the disease, the explanation obscurer than the facts.

Indeed, his enthusiasm for the living cell has carried

him some way beyond the facts, for contrary to his belief that organizing power is only exhibited by intact and living cells, Spemann has recently shown that the crushed cells of the dorsal lip of the blastopore —*zerquetschtem Organisator*—can induce medullary plate and other structures in host ectoderm. Marx, again, has shown that the organizing region is still effective when narcotized. These observations suggest a mechanism of an endocrinological character much more than "emanations from the nuclei." It may furthermore be mentioned that had Professor MacBride read my book more carefully, he would have seen that it is precisely to organizer phenomena of the kind revealed by Spemann's analysis that I would ascribe the facts of recapitulation. Professor MacBride speaks misleadingly of a "polemic against recapitulation"—but nothing of the kind occurs in my book. Of course, from those who consider recapitulation in the manner of a theological dogma, it is useless to hope for clear thinking on this issue.

Difficulty of Smallness.

Even in the appeal to "emanations," moreover, Professor MacBride does not go the whole way, but admits it as very probable that "these emanations have material substrates." However, as the "quantity of these substrates is out of all proportion small in relation to the magnitude of the effects which they produce," Professor MacBride is confident that biochemistry is, and will always be, impotent to deal with them. Here we see in its most characteristic form the desire of the vitalist to make the world safe for Mystery. But it is a desire that is doomed to disappointment, for the discoverers of vitamins, for instance, who first realized the extraordinarily small amounts of these important chemical substances which are necessary in our diet, have lived to see some of them isolated and their chemical constitution ascertained.

"That chemical embryology has so far had so little to say about the more strictly morphogenetic aspects of embryonic development is undoubtedly due to the fact that, just at the time when the embryo is most interesting, it is then also most minute. Had echinoderm blastomeres been as big as tennis balls, we should know a good deal at the present time about the metabolism of the cell in the cleavage-stages, and its relations with the assumption and determination of form. The destruction of one blastomere, for instance, in a regulation-egg, leaves its fellow, as is generally admitted, in a position of entirely different equilibria, and this must have a possible physico-chemical description, which has so far been impossible purely on grounds of technical difficulty. But let no entelechy congratulate itself upon its immunity from biochemistry on these grounds, for if one thing has characterized the recent history of that science more than any other, it is the ever-increasing delicacy of its methods." ("Chemical Embryology," page 1,626.)

As is inevitable in these discussions, Professor MacBride calls to his aid that ever-present help for the obscurantist, the regulation-egg, and sends forth, like some muezzin from a minaret, the age-old chant—"No machine, if divided, can give rise to two machines each of which will act exactly like the machine of which it was a part." It is all very colourful and picturesque, but do these anathemata help us? "No conceivable machine," says Professor MacBride, "can continue to act if the mutual relationship of its parts be disarranged" (page 95). May not the limits of the conceptual power of an individual mind be irrelevant to serious discussion?

What we can or cannot conceive is a matter of interest to psychologists; and chemical, exact, or mechanistic embryologists may readily reply that they find an impassable gulf between the living and the non-living worlds much more difficult to conceive. Let us freely admit that in the living cell we have to deal with the properties of a form of organization which is quite special to it. But let us not admit that this set of properties, this form of organization, is inscrutable, ineffable, any more than crystal form, or the colloidal state, is a form of organization beyond the understanding of human reason. "The heart's motion God alone can comprehend" said Frascatorius of Verona in the sixteenth century. "The egg's development God alone can understand," says (in effect) MacBride of London in 1932. Well, we shall see.

Need for New Concepts.

There can be no doubt that the physico-chemical knowledge which we have at present is inadequate to the full analysis of morphogenesis and determination. We may be waiting, indeed, for the arrival of some completely revolutionary concept, in the absence of which embryonic development must remain obscure and enigmatic. Of one thing only can we be certain, this revolutionary concept will not emerge from the prolonged incantation of old shibboleths, but from the painstaking analysis of scientific method, of biological notions, such as is now being undertaken by the mathematical logicians. Dr. J. H. Woodger's "Biological Principles," indeed, marked the end of the old period and the beginning of the new.

This revolutionary concept will fit on to, or be in some way congruent with, the mass of accurate physico-chemical knowledge which has developed during the last fifty years, as well as with the vast body of morphological knowledge which we have at our disposal. It will not partake of Professor MacBride's peculiar error, the error of supposing that the study of form is the province of the morphologist alone. Animal form extends from crude anatomy at one end to subatomic physics at the other, and the chemist who studies the spatial configuration of the molecules of a living organism is co-operating with the zoologist who studies the spatial arrangements of its limbs or its gut. Both are collaborating with the physiologist and biochemist, who take into account, not space only, but space-time, and examine the history of the living organism at all levels of its organization.

Even apart from form, we cannot suppose that biology and physics will never coalesce, as physics and chemistry have coalesced in our time. The task of uniting morphology and biochemistry is one of the most difficult in science to-day, but it must be mastered, for otherwise "the substance and the mode of organization of the substance will forever remain separated in our thought, one science studying the constituents without knowing how they are joined together in actuality, the other studying the joining, but the joining of nothing in particular." ("Chemical Embryology," page 1,664.)

"Chemical analysis applied to eggs," concludes Professor MacBride, "is an example of exact methods applied to inexact data." We are left to infer that morphological embryology is an example of inexact methods applied to inexact data. A more crushing condemnation of old-fashioned comparative embryology in its non-co-operative mood could not well be imagined.

Grassland Research in New Zealand.

NEW ZEALAND is, of course, mainly a country of grassland farming. Nearly 90 per cent of a total cultivated area is devoted to pasture, and large areas of native tussock country are used for this purpose. The present value of grassland products exceeds £50,000,000, and according to a recent report from the Department of Agriculture, this figure could quite easily be doubled by a wider appreciation of scientific methods. Much success has already attended the application of scientific research to grassland management. Since 1922 the total output of dairy produce, for instance, has been doubled and the annual yield of butterfat per cow has risen considerably. Progress has been largely due to the use of phosphate, nitrogen and potash fertilizers. Although the standard of grassland research now carried out in New Zealand compares favourably with that of any other part of the Empire, it is only within recent years that the work has been conducted on scientific lines. The changes which have transformed primary industries and the introduction of top-dressing of pasture, have resulted in the development of grassland management on an elaborate scale.

Research may be summarized under three headings. The Plant Research Station at Palmerston North is concerned mainly with seeds and fertilizers, subsidiary work on practical lines being carried out by officers of the department throughout the country. Progress in seed certification has definitely established the superiority of certain strains of grasses and clovers which can be isolated, thus enabling the output of grass and clover from a given area to be increased. Outstanding results have already been achieved which indicate that in addition to filling all home requirements, an extensive export trade in certified seed may be built up before long. Manure surveys carried out on experimental areas at Marton and in Canterbury have proved the value of certain fertilizers under a variety of conditions. Many farmers have found profit in investigations in this field. At Lincoln Agricultural College, Canterbury, research is concerned with the diverse nature of Canterbury farming, the most outstanding work being in connexion with wheat. At Lincoln also experiments have proved the nutrition value of certain materials which can be used as supplementary food with pasture under difficult conditions. The college has also done much in the cause of economy.

The Cawthron Institute, Nelson, is concerned with highly specialized work in many branches of research. Experiments on the mineral content of soils have proved highly valuable, as mineral content and animal health are, of course, intimately associated. The work includes the drawing up of detailed soil survey maps of the surrounding district.

Although the greater part of New Zealand's grassland is not yet efficiently managed, the increasing numbers of farmers who are taking up intensive cultivation is a tribute to the value of the research work done in recent years. The farming community is gradually becoming convinced that the scientific development of their grasslands is a vital factor in the present and future of farming in the Dominion.

Excavating the City of Hira.

By D. Talbot Rice, M.A., B.Sc.

Oxford University Excavations.

The recent excavation of Hira has yielded important information regarding the history and art of the pre-Moslem period in Mesopotamia. Interesting new light is also thrown on Christian art and architecture there in the seventh and eighth centuries. The author shows that this much-neglected period is well worth closer attention.

HIRA is rather an obscure name and the site itself appears also at first sight to be somewhat an obscure one, consisting as it does only of fairly low mounds. They lie in the desert some four miles to the south of Kufa and about six miles from Najaf, the most holy city of Iraq. This town is famous as the burial place of Ali, the first "Imam" of the Shia sect of Islam; the name of Kufa is renowned throughout the world, for it was this city that gave a name to the famous Kufic script. But of Hira we have heard little. The town was founded, we know, some time in the second century, probably because the Parthian city of Hatra in the north had become rather too unhealthy, situated as it was mid-way between the two great rival empires of the east, Byzantium and Persia.

A CHURCH AFTER EXCAVATION.

The large mass of walling in the centre marks the termination of the nave and the commencement of the eastern chapels. The eastern wall of the centre chapel can be seen on the left of the photograph.

At first Hira was little more than a permanent camp, but after a few years it had become a definitely established city and such it remained until the eighth or early ninth century. In 633 it capitulated to the famous Khalid who led the advance of Islam into Mesopotamia, and only a few years afterwards the neighbouring city of Kufa was founded in the place of Hira. The older buildings were gradually destroyed to provide brick for the Moslem edifices which were being constructed in the new town, but in spite of this it seems that Hira still remained inhabited for a century or so after the founding of its rival. With the Moslem conquest, however, it ceased to be a town of importance.

We are thus concerned with the period between the third and the seventh centuries, during which time the town was the capital of the Lakhmid kings, Arabs in race and vassals of the Sasanian Persians in practice. They were, however, extremely powerful vassals, and on them depended the protection of the western confines of the Sasanian empire. With Hira fallen, a direct road was open to the Sasanian capital of Mesopotamia, Ctesiphon. In accordance with this position, we see the Lakhmids raiding across the desert, attacking the Byzantine garrisons in Syria and making themselves the inveterate enemies of the Ghassanids, who played much the same role as upholders of the Byzantine power on the western side of the desert as did the Lakhmids on the eastern.

Both of them, in fact, were admirable buffer states which were maintained by their respective patrons as more or less independent kingdoms. The Lakhmids were unusually free, probably owing to their own power, for we read that one of their kings was buried in Syria while fighting on behalf of and not against the Byzantines, while another was responsible for bringing the famous Bahram Gur to the throne of Persia. This monarch, it seems, lived all his youth at Hira and was actually educated there.

The city was hence an extremely important one from the Persian point of view as regards its strategic position, and it was equally important commercially. Situated on a branch of the Euphrates and on the trade route from south to north as well as on that from south to east, its importance rapidly increased and its population apparently became quickly more and

more prosperous. In its earliest days it may have been little more than the permanent camp which the name " hira " implies in Arabic, but it did not remain so for long, and as early as the beginning of the fifth century we read that Hira was the seat of a Christian bishop. It remained a bishopric certainly until the Moslem conquest, and Christians lived on there for another hundred years or so.

They do not seem to have been in any way oppressed by their new masters, though we read rather sarcastic descriptions of certain religious processions which took place at Hira in the works of some Moslem writers. In early Abbasid days, at any rate, Christians were renowned for their learning; the medical profession was almost entirely in their hands and Mansur called for their aid and advice before he undertook the building of his new capital, Baghdad. It was only towards the third century of Islam that they died out in southern Mesopotamia, though they survived in the mountainous region to the north, and indeed they still survive there as a " religious minority " to-day.

A DOORWAY OF THE PALACE.
The carved stucco jambs are shown *in situ*. One is now in the Baghdad Museum and the other is on its way to the Ashmolean.

The older kings of Hira were not Christians, though some of the later ones may have been: among these was a certain queen mother, who founded a Christian monastery. Her predecessors were heathens, followers of one of the old cults of Arabia, one of whom even sacrificed four hundred nuns to the Goddess Al-Uzza, an event which can hardly have pleased his Christian subjects. Although many of them were Christians—we read that there were both Nestorians and members of the monophysite sect at Hira—there must have been as well adherents of the Persian state religion, Mazdaism, and Manichaeans too were doubtless represented. There must, in fact, have been a fine religious motley in the town, each faith having its own places of worship, and the excavation and examination of these is one of the most interesting problems which await the explorer. Last autumn we were lucky enough to find two churches, some of the earliest monuments of their class in Mesopotamia, which must be dated to the sixth or the seventh century. But as well there may lie hid fire temples of the Mazdaeans, sanctuaries of the Manichaeans or halls for the assembly of the worshippers of some little-known pagan deity from the Yemen.

Belonging as it does to this rather obscure period of history and situated as it was between the Persian and the Byzantine spheres, Hira may well provide us with much historical information of the greatest value. But in addition to that, the importance of the city in regard to the history of art cannot be exaggerated, for it is below the soil of such places that are to be sought the answers to some of the most debated points in the history of art and architecture not only of the whole Near East, but also of the whole of Christendom. Theory has run wild, suppositions have been boundless as to the character of Mesopotamian art in the early Christian period, but it is only now, with the commencement of excavation, that any exact data are beginning to appear.

German work at Ctesiphon some three years ago provided the most encouraging results, and our work at Hira was able to do more than substantiate them. One may now conclude without hesitation that there was in Mesopotamia at this early date, as well as a court art of Persian character, a definitely Christian art as developed and as important as the Coptic in Egypt and which had as much effect on the formation and development of Muslim art as did any other element, whether Coptic, Sasanian or Byzantine. It only remains for further excavations to be undertaken to disclose this art in all its aspects.

The work at Hira last autumn was done on behalf of Oxford University, and it was made possible by the generosity of Mr. Gerald Reitlinger. Professor Langdon acted as director of the expedition from England, and its sincere thanks are due to him for the keen interest which he took in the work. Excavations lasted for one month, and the aim throughout was to get some general idea of the site rather than to investigate separate areas in detail.

Nevertheless three fairly large buildings were cleared more or less completely. Two of these, as we have already noted, were churches. Both were of almost identical plan, having a long, basilica-like body with three aisles, separated by pillars and with three chapels at the eastern end. These chapels had square, not apsidal terminations. In them were found the remains of an elaborate frescoed decoration, and in one of the churches two layers of different dates survived, the lower one definitely Sasanian in style, the upper more akin to the early Moslem paintings from Samarra, though actually of earlier date.

In the churches, too, were found the remains of elaborate plaques of very delicate plaster-work, bearing designs composed of crosses. These must be assigned to about the seventh century. They show relationships with the stone carving of Armenia and suggest that the elaborately ornamented tombstones or wall decorations such as we see at Achthamar must have owed a considerable debt to the plaster carvings of south Mesopotamian churches.

In addition to the churches we were able to excavate one or two minor houses and one larger building which must be termed a small palace or castle. It stood to a height of two stories and was encompassed by an outer wall of burnt brick, though the walls of the rooms were of mud brick coated with fine white plaster. The doors were elaborately ornamented with jambs of carved stucco, some of which remained *in situ* though much more lay as it had fallen on the floors. We were able to remove a number of these jambs more or less whole as well as to collect the fallen remnants, and most of this is now being restored at the Ashmolean Museum at Oxford.

EARLY MOSLEM SCULPTURE.

Detail of a sculptured door jamb from one of the small houses. The fine carving shows Sasanian affinities though it is probably to be dated to the early Moslem period.

A FRESCOED CROSS.

On the eastern wall of the south aisle chapel in one of the churches a red cross frescoed on the wall remained *in situ*. It crumbled on exposure to the light.

The door jambs are probably to be dated to the beginning of the Moslem period, though the building from which they came is of earlier date. It had seen at least three periods of restoration and the door jambs probably belong to the last of these. Similar work was also found in some of the smaller houses, a fact which not only proves the richness of Hira at this time, but also suggests that we may expect important finds of the same class but of earlier date in the future.

Minor finds were plentiful. Some interesting glass which shows relationships with contemporary Byzantine work from Syria came from one of the churches and numerous specimens of pottery, glazed and unglazed, some akin to that from Samarra and elsewhere and some of a new type, came from the other mounds. A small bronze cross with loop at the top for suspension deserves mention, for it may well be of Byzantine workmanship.

The excavations were on the whole unusually productive, both in finds and in the information which they provided, and there is every hope that a future campaign would prove even more successful. The preliminary work has shown that this much neglected period is well worthy of closer attention in every respect, for it is not only an unknown period; it is something more. And it is to be hoped that even at this difficult time sufficient funds will be forthcoming to permit the continuation of the work.

New Uses for Hydrogen.

By E. F. Armstrong, F.R.S.

The study of hydrogen has led to outstanding discoveries in recent years and new applications for the element are continually being found. In the days of Boyle only a few cubic centimetres were available: to-day the industrial chemist handles millions of cubic feet per day, and the largest gas holder contains only a few minutes' supply.*

It was in 1841 that a meeting was convened in London to consider the formation of a chemical society, and its first general meeting was held five weeks later. What progress chemistry has made since that day, how vast are its applications, yet its vitality is as great as ever and the solution of old problems leaves but a greater number of new problems in their stead. This is particularly true of the element hydrogen. In spite of its antiquity as an object of chemical interest, the new problems presented by it to-day are leading to investigations in the very forefront of progress and of the highest importance both to theory and practice.

An Epic of Science.

Hydrogen is the simplest atom, the lightest gas. The chemists of old used the term spirit or air for what we to-day call a gas: it was not until the seventeenth century had two-thirds elapsed that it was agreed that there existed various elastic fluids other than air. Robert Boyle made ferrous gas (hydrogen) by the action of acids on iron and studied a number of other artificial airs. The story of the liquefaction of hydrogen is one of the minor epics of our science well worthy of being sung by a modern Homer. The experimental difficulties were great for the means then available in research laboratories, and those who were frequenters of the Royal Institution in the later nineties will remember the thrill the audience experienced as the new achievements were demonstrated to them in the historic lecture theatre by that master and artist—James Dewar.

The subject of hydrogen ion concentration is almost outside the scope of a paper dealing with hydrogen, the element, with which it has no real connexion. Yet the term is so often used in connexion with industry and with changes which take place in the animal body that it may not be out of place to refer briefly to it. Water, which is in so many respects a unique substance, has a slight electrical conductivity even in the purest form in which it can be obtained and it is, therefore, said to be slightly dissociated into ions of hydrogen and hydroxyl.

According to the most accurate measurements 1 molecule in 556 million molecules of water is so ionized. Solutions of salts, acids or alkalis in water are likewise dissociated more or less according to the concentration and in terms of the modern theory display varying activity, so that it is becoming customary and it is probably more strictly correct to speak of hydrogen ion activity than it is to speak of hydrogen ion concentration. Since a decrease in the concentration or activity of the hydrogen ion may be used to express an increase in that of the hydroxyl ion, one and the same scale can be used for the measurement of both acidity and alkalinity. Whereas titration of acids and bases measures potential acidity or alkalinity, it is the activity of the hydrogen ions which is in question when dealing with the reactions of the biological organism.

The use of hydrogen for the inflation of balloons dates from 1793. The gas for dirigibles must be reasonably free from impurities, and it must not contain even small amounts of any that are detrimental to the life of the containing fabric. It is easier and cheaper to produce hydrogen of high purity than to purify it later. In early days its cost was not of prime importance, but with the larger quantities required the cost has to be studied. At the beginning the gas was made by the action of sulphuric acid on iron, and we read of eighty tons of iron, together with 190 tons of sulphuric acid being required to fill a captive balloon at the Paris Exhibition in 1878.

The commercial methods of making hydrogen for airships are the electrolytic, the iron contact and the silicon process. This last is favoured for military purposes because of the small space occupied by the generator, the rapid production of hydrogen and the low capital cost of equipment, though the actual cost of generating hydrogen by it is too high for commercial purposes. It is also used in the navy in preference to compressed hydrogen.

Atomic Welding.

A special and most interesting application of hydrogen is in connexion with the atomic welding arc. The atomic welding torch is an arrangement of a jet of hydrogen gas through which an electric current is being sent. The hydrogen molecules are dissociated into atoms by the electric energy and these not only exert great chemical reducing power but by their interaction give a localized extreme heat

*Extracts from a lecture to the Royal Society of Arts.

suited for reducing and welding most of the refractory metals. The device, so simple in appearance, is the outcome of many years of experiment. Having studied the dissociation of hydrogen molecules for a dozen years, Irving Langmuir found that the recombination of hydrogen atoms to form molecules actually evolved more heat than the combination of hydrogen and oxygen and that such heat would even melt tungsten. The high temperature of the flame, together with its powerful reducing action and the avoidance of gases containing oxygen and nitrogen render the torch particularly useful for welding not only iron and its alloys but also such metals and alloys as contain aluminium, magnesium, chromium, manganese, etc. Substances of very high melting point such as tungsten can be melted with it : the important uses of tungsten in the electrical industry are based on this flame ; indeed the gas filled lamp is the direct result of experiments made for the purpose of studying atomic hydrogen.

The earliest technical use of the gas was for the inflation of balloons : subsequently it has found a number of other applications, including the hydrogenation or hardening of fats and of organic substances generally, the conversion of nitrogen to ammonia, and the hydrogenation of mineral oil and coal.

The commercial advantage of the fat hardening process is based on the fact that at the time of its invention the difference between the market price of tallow on the one hand and whale and certain liquid oils on the other, was as much as £15 to £25 per ton, and there was every indication that the world demand for hard oils was likely to exceed the supply. The cost of hardening was estimated to be of the order of £3 per ton. As so often happens, economic changes of another kind upset these expectations. The whaling industry was able to increase its prices, that of tallow fell so that when the hardening costs had been added to whale oil, the profit margin became much less attractive. In the end the hardening industry has served to maintain a balance between the cost of hard and soft fats.

Industrial Uses.

One of the results of hardening in America has been a considerable increase per head stated as 10 lbs. in the consumption of vegetable oils : this has been commented upon as one of the most striking changes in food consumption that has taken place in recent years. The hydrogenation of other organic substances than the fats is being practised to an increasing extent on a technical scale, and there is every indication that as the practical uses of the products so formed increase, the method will become one of prime industrial importance in the great field of applied chemistry.

Most of the products that have been hydrogenated are used in the ever-growing solvent industry, which has given the world the new cellulose lacquer paints and varnishes, or in the artificial silk industry. Their use is extending daily and leading to novel and valuable products of every day utility. Perhaps the most important on this list is synthetic methyl-alcohol or methanol, which thus becomes a product of water gas and can be produced at a far lower cost than formerly when it was obtained as one of the products of the destructive distillation of wood. Besides its important use as a methylating agent, methanol is the raw material for formaldehyde, a chemical of the widest utility, one of its prime services being the manufacture of synthetic indigo.

Water Gas Process.

Much has been written about the conversion of nitrogen to ammonia. For economic success most depends on the cost of hydrogen which has been steadily reduced as the result of experience. Three rival methods of making it have been tried. The electrolytic, when very cheap power is available, is not yet out of the race. The most favoured is the water gas process, but there are many believers in coke oven gas as the ideal raw material for hydrogen production. It is worth while discussing their relative merits if only as an example of the many factors to be considered in an economic question of this kind.

Water gas is made by blowing air and steam alternatively over coke in a producer. Coke oven gas is a by-product of the ovens producing metallurgical coke for the steel works in this country, though both in America and Germany it is piped to the nearest gas works for use. When using it for ammonia synthesis all the constituents other than hydrogen and nitrogen are separated by the combined use of pressure and low temperature. The carbon dioxide is removed by washing at low pressure as above described. The gas is then fractionally cooled, whereby first the methane and then the carbon monoxide are removed.

The nitro-hydrogen mixture when adjusted to the proper proportions is ready for use. Taking each process under the most favourable large scale conditions, the cost of hydrogen by either of them is much the same, being about one shilling per thousand cubic feet. If an ammonia plant be located at or near a coke oven works, it is spared the capital cost of erecting producers. Against this saving must be set the fact that the hydrogen and hence the ammonia

become by-products of the coke industry, and the site may not in other respects be favourable for ammonia production.

The ammonia is sold in the form of sulphate of ammonia prepared either by neutralization with sulphuric acid, or double interaction with sulphate of lime (gypsum) and carbon dioxide, the other product being a carbonate of lime suitable either for agriculture or for cement. The synthetic sulphate competes with that obtained in the gas works and latterly the price has been brought down so low by unreasoning competition that it costs more to recover the ammonia from the gas than can be obtained for it. Synthetic ammonia plants have sprung up in every country—to-day their total capacity is estimated at four million tons per annum, whereas the total sales have only reached a figure of $1\frac{3}{4}$ million tons.

The two uses of hydrogen we have already considered form more or less completed chapters; its use in conjunction with oil and coal is only on the threshold of industrial application. This is a subject of absorbing interest the world over; very large sums have been spent in experimenting and perfecting; nowhere as yet are plants in existence on a commercial basis. Though the problem has been solved technically it is still far from being economically attractive.

Thanks to the advent of the internal combustion engine this is an age of oil; on land or sea and in the air oil reigns supreme. There have been fears as to its possible exhaustion, as yet we have really used very little of it in total; at first it was wastefully produced. Oil displaces coal; therefore, the question arises can it not be produced from coal in greater quantity than the tar or oil is produced in a gas works. Coal made into a paste can be hydrogenated under pressure to oil and to-day a large yield of oil, mostly petrol, can be obtained from a suitable coal. The by-product is mainly methane from which hydrogen can be made when it interacts with steam in presence of a catalyst. The plant is an elaborate and costly one and so far the cost of producing petrol is put down at 7d. to 8d. a gallon which has to compete with a price of less than 2d. a gallon at the oil field.

Hydrogenation of Tar.

The second half of the problem is the hydrogenation of tar. This, as produced from coal either at a gas works or by low temperature carbonization, contains less hydrogen in proportion to carbon than does natural petroleum. Such oil can be readily hydrogenated, yielding a commercial quality of petrol of high anti-knock value. Such low temperature oil can be hydrogenated more cheaply than coal and once it is available in really large quantities, a new home oil industry could be built up on it. It is only produced, however, together with a smokeless coke fuel in such proportions as twenty gallons of oil to thirteen hundredweight of the fuel: this fact makes the production of the oil, viewed from the commercial standpoint, essentially one of the production and sale of low temperature fuel. Until the coal factors and the public are educated to using such fuel, the quantity of oil produced even in countries which have no native supply will lag behind the potential demand for it.

Research in America.

Many of the residues produced in refining oil are of low value; hydrogenation converts these into much more valuable products. Large experimental plants have been built in America to study this question on a commercial scale and have met with success, and there is every reason to suppose that but for the present glut of natural oil they would have become part and parcel, along with cracking and refining plants, of the oil industry.

One of the good features of the hydrogenation process which in the future may have some bearing on its application, is the property hydrogen has of removing the noxious sulphur in the form of hydrogen sulphide gas. Should the oil industry ever take seriously to hydrogenation, it has a potential cheap source of hydrogen available in the form of methane which readily interacts with steam forming hydrogen and carbon dioxide: either natural gas or waste refinery gas are at hand in large quantity at the very lowest cost so that oil hydrogenation will have much cheaper hydrogen available than any ammonia plant.

A philosopher has said that we cannot deserve the future unless we honour the past. The story of hydrogen is one which involves the mention of many names, men who worked almost without apparatus and laboratory equipment in the modern sense, and we can but marvel at how much was achieved. The study of hydrogen has continually led to new discoveries, and it is certain that we have far from reached the end of all that there is to know about its atom and its molecule, its behaviour under conditions of high pressure or electrical excitement such as it will be exposed to in the laboratories of the future. In its application to industry, to the service of man and his needs, it has been described how hydrogen, won underground from coal, that is, from the remains of fossil plants laid down in past ages, can be used to build up some of the most urgent needs of man as well as to make substances which minister to his luxury.

Book Reviews.

Scientific Riddles. By Sir J. Arthur Thomson. (Williams & Norgate. 10*s*. 6*d*.).

This is a delightful book. The author has a well-deserved reputation for writing about scientific subjects in a popular and attractive manner, with an avoidance of technical terms, in language that can be understood by the multitude; and in this book he has lived up to his reputation. It is not a treatise on one scientific theme, but rather a series of short "musings" on no less than fifty-two different subjects. These range from the fundamental problem of the origin of life to such disputable subjects as telepathy, clairvoyance and crystal-gazing. These essays are charming to read, never too long to tire the patience, and of such a character that it is not necessary to begin with the first; but the casual reader can begin almost at any point and derive pleasure and profit from what he reads.

The diversity of subjects renders criticism of the book exceedingly difficult. There is a great deal in it with which we are in complete sympathy, but complete agreement is dull to record. One of the great discontinuities in nature is the first appearance of life—it is as great a discontinuity as the primary aggregation of matter in the universe. If, as Sir James Jeans says, the study of the cosmos points back with irresistible logic to an event or events in the past which we can only describe as creation, so does the study of life. It is one of the primary characteristics of living beings that they can only originate from pre-existing living beings. But since the earth was once red-hot and life can only exist between narrow limits of temperature it must have originated at some point in past time. The author lays stress on the experiments of Baly, who claims to have synthesized formic aldehyde and even sugar from Co_2 and water, in the presence of sunlight. Then if we assume that some such synthesis occurred in the primeval sea and that nitrogen compounds were produced by lightning flashes and that inorganic metallic salts were leached out of the primary crust of the earth by water, we should have, he thinks, all the essential elements of protoplasm produced from dead matter. But apart from the fact that the sugar found by Professor Baly has been shown to be due to a previous contamination of the water used, even if all these happy accidents combined, we should get merely a mixture of substances and not living protoplasm. In such a mixture, chemical action would occur but this would proceed until a steady state or equilibrium was attained. In real living beings the average state of the mixture is kept constant by the miracle of synthesis or anabolism: and the more we study the physiology of the simplest living beings, the more it is seen to resemble that of higher beings and the more it is seen to differ from a mixture of chemicals in a test-tube.

In one of the concluding essays Sir Arthur deals with the origin of the "new" in evolution. He says that we owe to the "clear thinking of Weismann" the idea that the novelties which form the raw material of evolution are due to "permutations and rearrangements" in the germ-cells. On this matter the author is, perhaps, a little out-of-date. Indeed Prizibram, one of our most distinguished experimental embryologists, recently spoke of the "four fundamental dogmas of the Weismannic religion" as "shown to be false." Changes in the germinal material of eggs have undoubtedly been produced by X-rays and have given rise to inheritable "mutations," but these mutations are always characterized by physiological weakness and would in wild conditions be at once removed by "natural selection." In fact, one of our leading geneticists expressed the opinion that these X-ray experiments have definitely killed the idea that mutations could have played any part in evolution. The real cause of evolution is change of habit under stress of the requirements of an altered environment, and that a habit acquired in this way is in some measure passed on to the offspring has been proved up to the hilt. One of the series of facts which supplies the strongest *indirect* evidence of this is the migration of birds, a subject in which the author's distinguished son, Dr. A. Landsborough Thomson, has done brilliant work.

But these differences with Professor Thomson are minor matters. We have read the book with delight and we are sure that this will be the experience of every other reader.

The Coinage of England. By Sir Charles Oman. (Clarendon Press. 21*s*.).

English Coins. By G. C. Brooke (Methuen. 22*s*. 6*d*.).

A new guide to English coins has long been needed. Dr. Grueber's handbook, published more than thirty years ago and long out of print, was first-rate in its day, but much has been learned since he wrote, as every reader of the *Numismatic Chronicle* knows. By strange good fortune the demand is now supplied twice over. Two excellent books by most competent authorities have appeared simultaneously, and it would be hard to choose between them. Professor Oman is primarily a historian but he has always taken a keen interest in coins, Greek and Byzantine as well as English. Dr. Brooke is attached to the Department of Coins at the British Museum and is well known as a specialist in English issues. As might be expected, they have somewhat different aims. Professor Oman studies our coinage, from the Anglo-Saxon period to the death of Queen Victoria, from the historical standpoint. He is interested in its administration and financial aspects as well as in the coins themselves, and shows how they illustrate political changes and economic follies. He enters into much curious and instructive detail and makes his narrative extremely readable. On the other hand, Dr. Brooke, who covers the whole subject to the present day, is concerned above all to provide a trustworthy book of reference for those who wish to identify coins. He has compressed his historical introductions to the several chapters and gives more space to precise descriptions of the coins, period by period. These are illustrated in sixty-four pages of photographs finely reproduced by collotype. Professor Oman has contented himself with forty-five pages of the old but very clear engravings from the *Numismatic Chronicle*, which suffice for most purposes. We may say that for ready reference Dr. Brooke's work has the advantage, while as a guide to this extremely fascinating branch of our history Professor Oman's is preferable. But both books, we must repeat, are excellent.

The currency problem which concerns us so deeply is not new. Bimetallism was a source of endless trouble in the Middle Ages and up to the reign of George III. To keep gold in its correct relation to silver and thus to prevent either metal from being hoarded or exported was a Sisyphean task. Before the fourteenth century gold coins were exceptional in England, though Offa of Mercia in the eighth century struck a gold coin imitated from an Arabic dinar and later kings occasionally followed his example. Edward III was the first king to coin gold regularly, after the manner of France and Florence, because increasing trade made a mere silver currency inconvenient. He fixed a ratio of twelve to one, but as the supplies of gold and silver were continually expanding or contracting, the ratio had to

change with them. Modern bimetallists might learn something from the sad experiences of our mediaeval kings. The evils of a debased currency are well exemplified in the reign of Henry VIII, who was the worst offender in our history and had the least excuse for his frauds. He issued silver coins which were two-thirds alloy and required his people to assume that silver stood to gold as one to five, at a time when the import of silver from Spanish America was forcing the price downward. His later Festoons—shillings so called because they had the King's head—had so thin a coating of silver that the King's face soon showed the copper underneath, and impudent lieges therefore referred to him as "old copper nose." Elizabeth's restoration of the coinage in 1560-1 was one of her greatest achievements. Oddly enough, she made an unexpected profit in it, whereas the next great recoinage, in 1696, cost £2,700,000, which was found by means of the window tax.

It is no surprise to find that Professor Oman and Dr. Brooke differ on many small and highly technical matters. All numismatists do. But it is odd that they should be in disagreement about the familiar tradition that the original of Britannia, first introduced on Charles II's halfpence and farthings in 1672, was "La Belle Stewart," Frances Stewart, Duchess of Richmond, so well-knwon from Lely's portrait and Gramment's memoirs. Dr. Brooke says that "for the figure of Britannia, which was adapted from the Roman type of Britannia of the second century, the Duchess of Richmond sat as a model." But Professor Oman describes as "a fanciful legend" the tradition that it was a portrait of the Duchess. "Portraiture on such a small scale was impossible." Who shall decide when doctors disagree?

A Nature Calendar. By E. Fitch Daglish. (Dent. 6s.).

This is a collection of weekly articles written for *Everyman*, revised by the author. They form a very readable record of Nature out-of-doors in every month. Backwoodsmen will appreciate the author's correction of the town dweller's idea of the country in winter as a quagmire set in a monotonous grey landscape; at no time is rural England devoid of colour nor uninteresting to those with seeing eyes. Mr. Daglish's chronicle touches upon birds, flowers, butterflies, frogs, spiders, galls, fungi and many other subjects. His conclusions on the enormous mortality in young birds, though they tell nothing new to the ornithologist, will be illuminating to the amateur bird-lover. He estimates that out of possibly forty-five young produced by one pair of blackbirds in three years, only two live to maturity. Probably this is not far wrong, and the same applies to many other species.

He writes understandingly on the strange ability of some birds to do without drinking, though others need to quench their thirst frequently. He states that nestlings of our native birds are "never" given water. "Never" is a dangerous word. Mr. Oliver Pike has described how he saw a hen raven convey water in her pouch from a stream to her thirsty nestlings on a very hot day, and we have observed grey wagtails dipping food in the river before taking it to their young in the nest. But such feats are exceptional. He explains the formation of the curious circlets still called "fairy-rings" by rustics, and the assumption by certain animals of white coats in winter. The statement that hibernating red-admiral butterflies are rarely seen before late May may be generally correct, but we have noted them in Somerset every month from December to March.

Mr. Daglish's wood engravings are well known; this book has a dozen of them. The best are those of flowers, fly-agarics and the great grey shrike. The absence of an index is regrettable.

African Small Chop. By Sir Hector Duff. (Hodder and Stoughton. 8s. 6d.).

This is an absorbing book in which the author records his experiences, observations and conclusions during and since his period of service in Africa which began in 1897 as Assistant Resident in Nyasaland. Sir Hector eventually became Chief Secretary to the Government with a seat on the Executive and Legislative Councils. He explains that "Small Chop" is pidgin English for a snack; the title fits the book, for it is an interesting collection of random jottings on almost every facet of life in the colony. The author discusses the extinction of native races as a result of colonization all over the world. He makes a distinction between countries which Britain governs without colonizing, like India,and colonies proper. He mentions the extinct indigenous Tasmanians, the fewness of the remaining Australian myall blackmen, the dwindling Polynesian islanders and North American redskins. He agrees with Darwin that the probable cause is that the general change of habits, induced by civilization, destroys the fertility of such people. But within that mystery, he says, is another.

"How comes it that a single African stock, the African negro, continues to survive and flourish side by side with us while all others decay? This solitary exception to an otherwise universal rule is one of the strangest facts in ethnology. If ill-treatment could exterminate any people, or altered habits impair their powers of breeding, the indigenous tribes of Africa must have been an extinct, or at least a dying, race by now, for no natives have ever been so mercilessly exploited or subjected to greater changes in their environment and mode of living." Mentioning the ravages of the slave trade, which removed thousands of natives to a new continent, Sir Hector says that the Bantu stock continues to flourish and multiply not only in the country of its origin, but in the West Indies, the United States, and wherever its imperishable blood has been introduced. But the survival is only physical: "Not having succeeded in wiping the aboriginal Africans out of existence we are putting them into trousers and so destroying them in another way, by transformation."

The author declares that "next to the scientific outlawry of the anopheline mosquito, I reckon the presence of white women has done more than anything else to improve the conditions of life and lower the rate of death in tropical Africa through its persistent war on dirt, waste, bad cookery, solitude, boredom and the results of these. . . . Looking back on Africa as I knew it first and as I knew it last, and all that has been done there in that time, I would not give up the part of it we owe to women for half the man-made ordinances from Kenya to Sierra Leone."

Many extraordinary fish are hidden in the equatorial lakes, and there are stories of monsters supposed by some to be survivors of the saurians. Seeing a huge creature in Lake Nyasa one day, the author set out with a friend in a boat to investigate. When they were close enough Sir Hector's friend put two rifle bullets into the strange object, which heaved slowly over, giving a glimpse of a great shining porpoise-like body as big as an elephant, and vanished into the deep without a sound. As a result of this experience Sir Hector believed in the existence of monsters in the lake, until an explanation

was given by the skipper of a lake steamer. He explained that he had seen such an object some years before, and bringing his ship alongside it, had discovered it to be the body of a dead hippopotamus fantastically swollen by putrefaction and driven by winds and currents about the lake. The rifle shots in the instance in which Sir Hector had taken part had let out the accumulated gases that kept the carcase afloat.

The Elements of Biology. By C. Von Wyss. (Christopher. 6s.).

Chiefly owing to the continued neglect of the study of biology in schools, the educated public unfortunately takes less interest in biological progress than in the more spectacular achievements of physics and astronomy. This small volume should do much to stimulate interest in the "science of life." It cannot be described as a text-book, yet it is admirably adapted for use in connexion with school-work. Readable and devoid of laborious detail, it aims rather at interesting the reader to investigate for himself, than at pointing out minute detail. Illustrations are well chosen and numerous.

Fully one-half of the book is descriptive of the march of the seasons, and here the reader is informed of the life-history of many of the typical plant and animal inhabitants of the countryside. The following more detailed study of some primitive animals and plants helps the reader to understand something of the origin of the higher, vertebrate animals, among which the frog and the rabbit are studied at greater length. The process of reproduction is introduced by consideration of ferns and flowering plants, followed by a study of the development of both tadpole and chicken. Towards the end brief reference is made to the struggle for existence and it is shown how living plants and animals form communities of which the members show much inter-dependence, besides responding, each in its own way, to the conditions of their common environment. Instances are given of the successful biological control of insect pests, and the benefits to be derived from biological research, promising, as Sir Arthur Thomson points out in the foreword, "the relief of man's estate that must follow when we all form more persistently the habit of thinking biologically."

Philosophy of the Sciences. The Relations Between the Departments of Knowledge. By F. R. Tennant. (Cambridge University Press. 6s.).

Philosophical Aspects of Modern Science. By C. E. M. Joad. (Allen & Unwin. 10s. 6d.).

To the physicists and mathematicians who have invaded the realm of philosophy with their own theory of the universe, the philosophers are now beginning to reply with vigour, as if to put the intruders in their place. The two new and able books by Dr. Tennant and Mr. Joad, mainly directed against Sir James Jeans and Sir Arthur Eddington, are well worthy of attention. The object of Dr. Tennant's Tarner lectures at Trinity College, Cambridge, is to discuss the relations of typical sciences to one another and to knowledge as a whole. He insists on the comprehensive view. "The eminently learned in our sphere of knowledge sometimes make incursion into another sphere in which they are not equally at home, and are then apt to propagate erroneous beliefs." And he unkindly refers to the "theologians venturesome enough to steal their honey, when it is of the right flavour, for the theological hive." The natural sciences are useful, within their limits, as are history and dogmatic theology, each of which he recognizes as a science. But he will not accept the specialist's theory of the universe as philosophically sound. His argument, though condensed, is clear and impressive.

Mr. Joad's book, which covers much of the same ground, but is more specifically concerned with the physicists and Mr. Bertrand Russell, is as usual vivacious in style and easy to read. His critical analysis of the theories of Eddington and Jeans contains much shrewd and witty comment. The essence of it is in his conclusion. "Science, in fact, cannot be maintained beyond a point; at the furthermost limits of scientific explanation the mind passes into another sphere which is not the world of science but the world of value. Hence the importance of scientific knowledge at the present stage of mind's evolution lies in the fact that it prepares the way for the revelation of a world beyond scientific knowledge." The scientist may think that he has grasped reality when, in fact, reality has escaped him while he was scrutinizing its several parts. We shall not attempt here even to summarize Mr. Joad's argument, but it is persuasive.

The Religion of Scientists. Edited by C. L. Drawbridge. (Benn. 2s. 6d.).

The Rev. C. L. Drawbridge, on behalf of the Christian Evidence Society, has collated the replies of two hundred Fellows of the Royal Society to a set of six questions on the subject of religion and theology. In addition to analysing the replies numerically, the editor has quoted the comments of many famous scientists. To the key question, "Do you credit the existence of a spiritual domain?" 121 answers were in the affirmative and only 13 in the negative. Sixty-six Fellows did not reply at all, or did so in terms too indefinite to allow of classification. "Do you consider that man is in some measure responsible for his acts of choice?" was next asked, and to this 173 answers were affirmative and only seven negative. Twenty Fellows did not reply or were indefinite. Only six Fellows said "No" to the question "Is it your opinion that belief in evolution is compatible with belief in a Creator?" but 142 said "Yes," while 52 did not reply or were doubtful. By four to one the Fellows do not believe that science negatives the idea of a personal God as taught by Jesus Christ (103 against, 26 affirmative, 71 no reply or indefinite); and in view of this the replies to the next question are provocative of thought. The question was "Do you believe that the personalities of men and women exist after the death of their bodies?" More than half, 112, of the Fellows either did not reply at all, or were indefinite, and of the remainder 47 said "Yes," and 41 "No." Thus many of the Fellows believe in a personal God, but not necessarily in survival after death. Seventy-four Fellows are of opinion that the recent remarkable developments in scientific thought are favourable to religious belief, 27 think that such developments are unfavourable, while 99 did not reply to this question or were indefinite.

Caving. Episodes of Underground Exploration. By Ernest A. Baker. (Chapman & Hall. 15s.).

In the intervals between writing fiction, editing a dictionary and compiling anthologies, Dr. Baker has found time in the last thirty years for a great deal of exploration in underground

caves. Into this book he describes a host of adventures underground. He has made a fascinating recreation as well as a serious study of his work and quotes the wit who described cave exploring as "mountaineering reversed."

Although caves occur in all parts of the country, the principal systems are, of course, in the Mendip Hills, the West Riding of Yorkshire, and Ireland. This book is divided into sections accordingly and there are also chapters on caves in France and Belgium, and those in and around London. The author declares that the much-advertised Chislehurst Caves are merely "chalk mines of comparatively recent origin." He records in some detail his investigations which led to the controversy about the caves a few years ago. He comments on a "dissertation by the learned antiquary, accepted as a text-book by the guides and those believing in the vast age of the caves," and discredits the belief that the caves were ever used by Druids. Their age, he says, is to be measured by decades, or possibly a century of two, not by milleniums. One of the most interesting chapters deals with the cave village of Wookey, in Mendip. Dr. Baker writes that during the nine centuries from 500 B.C. until the time of the Roman departure from Britain, Wookey Hole was occupied by communities, not merely by solitary individuals or families. He adduces as evidence finds of prehistoric remains in the caves. In the course of his expeditions the author experienced many narrow escapes from disaster. On one occasion he was shut 400 feet below the ground surface with a flood above. To this and other adventures he has done ample justice. The book is lavishly illustrated with more than 100 photographs and with plans and diagrams.

The Cambridge Medical School. A Biographical History. By SIR HUMPHRY DAVY ROLLESTON, BART. (Cambridge University Press. 15*s*.).

The Regius Professor of Physics at Cambridge has compiled, at the cost of much labour, a trustworthy account of the medical school over which he presides with notices of the many physicians, surgeons and others who have taught in the university since the reign of Henry VIII. It is necessarily a severe book, but there are enlivening passages for those who care to seek them. John Caius, who refounded Gonville Hall as the college which bears his name, was the true father of Cambridge medicine, but he lectured in London and not in Cambridge. It is sad to find that this worthy man, who gave all his wealth to the college of which he became Master, was scurvily treated by the younger dons. During his absence in 1572, the year before his death, his rooms were looted and the "popish trumpery" found there was burnt in the college court while three other heads of colleges looked on. Sir Busick Harwood, the first Downing Professor of Medicine, was a noted *gourmet* and wit. During his morning walk he collected guests for luncheon, "carved the turbot which had been dissected by his demonstrator for the previous day's lecture," and then was unkind enough to detain his guests for his afternoon lecture. He "ingeniously arranged that a presentation of plate should be made to him, and, when the subscription was limited to two guineas, anonymously sent a banknote for fifty pounds." In those days it was not unusual for the holder of a scientific chair to be profoundly ignorant of the subject that he was expected to teach, like Richard Watson, elected Professor of Chemistry in 1764, who then began to study the science and became eminent. The play of "The Anatomist" has revived memories of the "resurrection men" who supplied subjects to the dissecting room. The author duly mentions that the body of Laurence Sterne, who died of consumption in 1768 and was buried in London, appeared in Collignon's anatomy theatre at Cambridge a few days later. Sterne would have appreciated the grim jest. Sir Humphry Rolleston's brief sketch of the history of his great medical school stresses the rapid progress made from about 1870 under the guidance of a few able and energetic men like Sir Michael Foster. The numbers of students are now all too large for the clinical material available, and the author would have the university establish a post-graduate research hospital. The book is fully illustrated with portraits and has a good index.

Heimskringla. The Lives of the Norse Kings. By SNORRE STURLASON. Edited, with Notes, by ERLING MONSEN. (Heffer. 18*s*.).

Snorre Sturlason was born in Iceland in 1178, the son of a powerful family of Icelandic chiefs. Although a lawyer of note he had been engaged from his youth in literary work, and his best known book, "The Edda," was completed in 1220. This was followed about ten years later by "The History of the Norse Kings." Copies were known both in Iceland and in Norway. The oldest known copy on parchment was called "Kringla," and was kept in Norway until the end of the sixteenth century. Later the manuscript was sent to Copenhagen, but by this time it had lost its first page. The second page, which was now the first, began with the words *Kringla heimsins* (the world's circle); hence the title of this book. In his preface Sturlason wrote: "In this book I have written the old narratives about the chiefs who have had realms in the Northlands, even as I have heard wise men, learned in history, tell." The first translation of the book into English was made by Samuel Laing in 1844, followed by William Morris' version in 1893. Those who are acquainted with this edition—characteristically in nine volumes and largely in old-fashioned English—will welcome the publication of the work in a form more suited to these hurried times.

Sturlason's history is an inspiring work, and the illustrations in line are appropriate and effective. More ambitious embellishments would have been out of keeping with the simple but forceful nature of the narrative. The translation (a difficult task) is sympathetically done and the introduction is an asset. The book is handsomely produced.

Man's Microbic Enemies. By D. STARK MURRAY. (Watts. 1*s*.).

An informed public will generally avail itself of every measure of protection against the scourge of disease. In this little volume, one of the latest additions to the Forum Series, the author outlines in simple language the nature of the difficulties which the bacteriologist must surmount if the war he is waging on man's microbic enemies is to be generally successful. Undue stress is not laid on successes achieved, but a readable, informative account of the subject is given in the small space available. The importance of bacteriological research and of the protection so far obtained is, however, made clear.

The pioneers in this field of research are not forgotten. Their contributions to our knowledge of the cause and cure of disease were immense compared to which later advances may be considered arduous and slow. It is shown how modern research opens up possibilities of greater successes in several directions.

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